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#210 NOVEMBER 2022

Sky at Night

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HOW THE MOON WAS MADE

Tour 8 striking lunar features that reveal its long and dramatic past

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Welcome

Take a new look at the Moon – it may surprise you!

The Moon is our constant companion in the night sky, its cycle of waxing and waning so engrained that ancient humans set calendars by it, and modern humans may only give it a passing glance. Yet look closer at the Moon – with binoculars or a telescope, if you have them – and you'll see its surface bears the scars of a violent and tumultuous past. This month, Will Gater picks out eight of these dramatic surface features to give us a remarkable insight into the Moon's history, from colossal collisions to volcanic activity, and myriad asteroid and comet impacts. Turn to his feature on **page 28**, then go out and see the Moon in a new light!

Astronomy author Govert Schilling talks about new light in his report on the Vera Rubin Observatory on **page 34**. He paid a visit to this revolutionary new telescope, currently nearing completion in Chile, to find out about its mission to create the most comprehensive study of the southern sky ever made, using the largest digital camera ever built. Capturing a whopping 200,000 images each year, this is going to be a database so deep that it will enable scientists to uncover how clusters of galaxies have evolved and reveal the influence of dark matter, the mysterious force thought to be driving the Universe's expansion.

Turning to setups you're more likely to use at home, on **page 61** Paul Money investigates deep-sky imaging using Go-To altaz mounts. If you thought an equatorial mount was essential for far-distant targets, what he has to say may interest you!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 17 November.

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

Online
Visit our website for competitions, astrophoto galleries, observing guides and more

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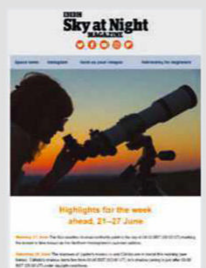

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Ⓒ = on the cover

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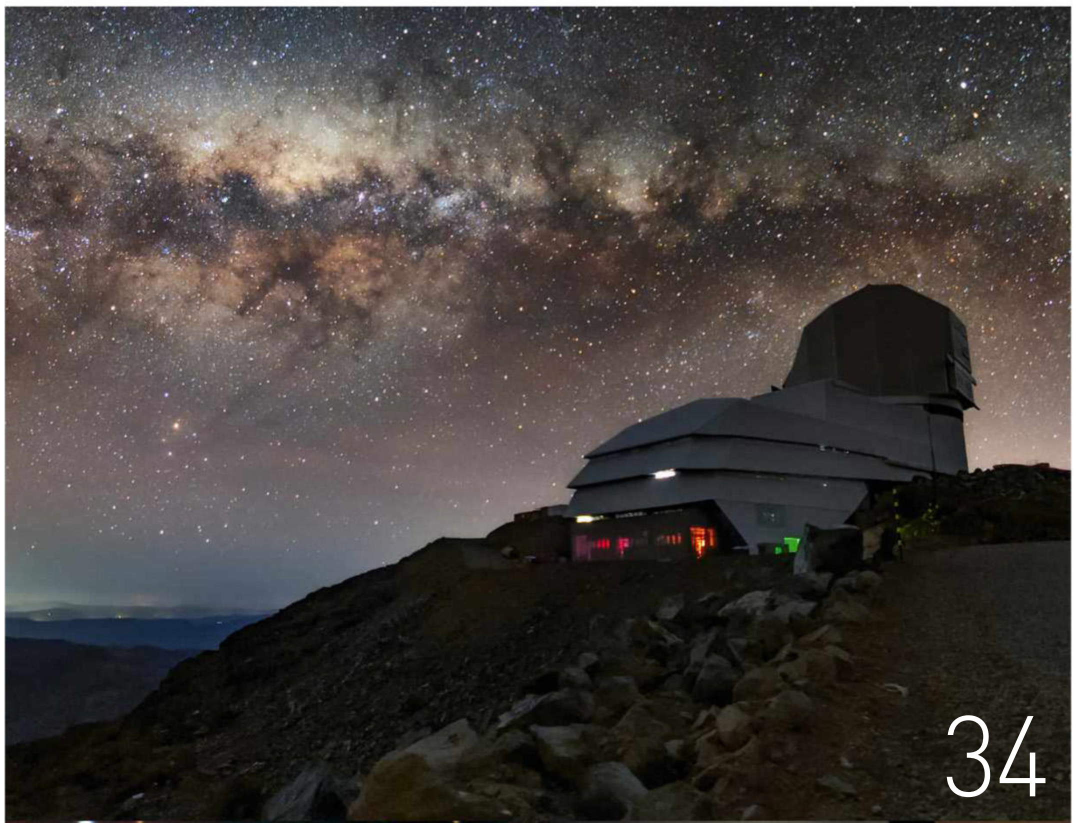
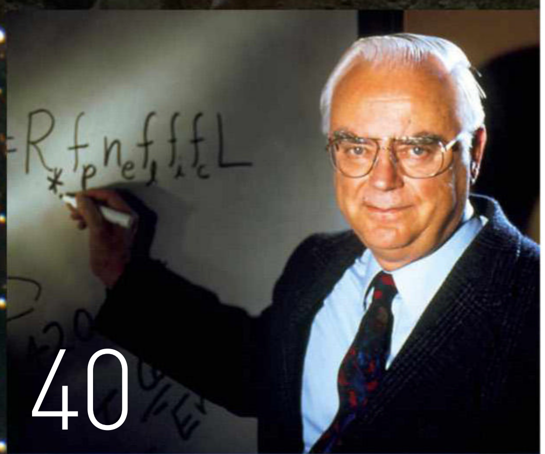
The Sky Guide

16-PAGE CENTRE PULLOUT

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**





This month's contributors

Will Gater

Astronomy journalist

"I really enjoyed diving into the rich history of the Moon this month and bringing together some of the features that let us observe our way through its extraordinary timeline." **Take Will's lunar tour on page 28**

Govert Schilling

Astronomy author

"I visited the Vera Rubin Observatory while it was still under construction. Hopefully, the new telescope will help solve the riddles of the dark Universe. I can't wait to see the first results!" **Read Govert's story on page 34**

Niamh Shaw

Space communicator

"SOFIA has given astronomers a unique infrared view of the Universe. I was privileged to accompany scientists on one of its final flights." **Join Niamh on board as the airborne observatory says farewell, page 66**

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/GD67VIT** to access this month's selection of exclusive Bonus Content

NOVEMBER HIGHLIGHTS

Interview: Amazing cosmic facts

Astrophysicist Dr Jillian Scudder guides us through some of the most mindblowing quirks of the cosmos.

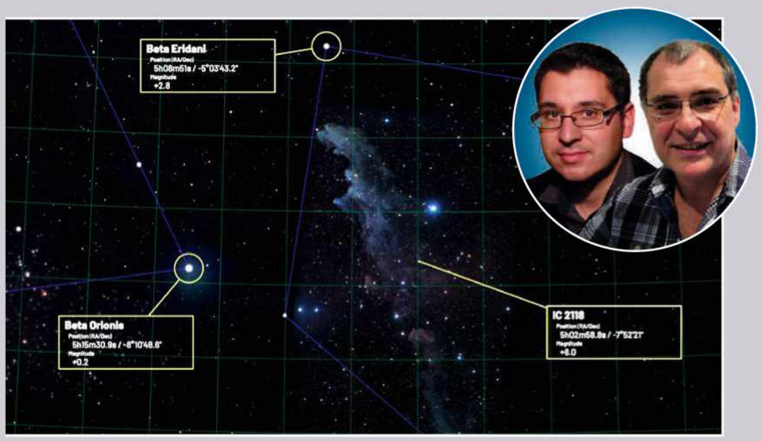
Photographing the Universe

In this special episode of *The Sky at Night*, the team reveal how you can capture images of what you see in the night sky.

DIY astronomy: How to build a sextant

Download extra materials to help with this month's project: building your own celestial navigator.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

CONSIDER THE LOBSTER

This spectacular image marks 10 years of Cerro Tololo Observatory's dark-energy-hunting camera

VICTOR M BLANCO TELESCOPE, 12 SEPTEMBER 2022

MORE **ONLINE**

Explore a gallery of these and more stunning space images

The Lobster Nebula, NGC 6357 in Scorpius, glows majestically in this image taken by the Dark Energy Camera (DECam) at NOIRLab's Cerro Tololo Inter-American Observatory, high in the Chilean Andes.

The 570-megapixel image shows a star-forming region 8,000 lightyears from Earth in which twisting braids of dust are shaped by magnetic fields, winds and radiation, and protostars shine through cocoons of the material that formed them.

It was released to celebrate DECam's 10th year of operation, a decade in which the four-tonne camera, the Blanco Telescope's primary instrument, has taken over a million images. Studying hundreds of millions of galaxies, their motions and conditions, its mission is to investigate the mystery of the unknown force that seems to be speeding up the expansion of the Universe – dark energy. Joining the hunt is the upcoming Vera C Rubin Observatory, which you can find out more about by turning to page 34.

CTIO/NOIRLAB/DOE/NSF/AURA

◁ △ The two Tarantulas

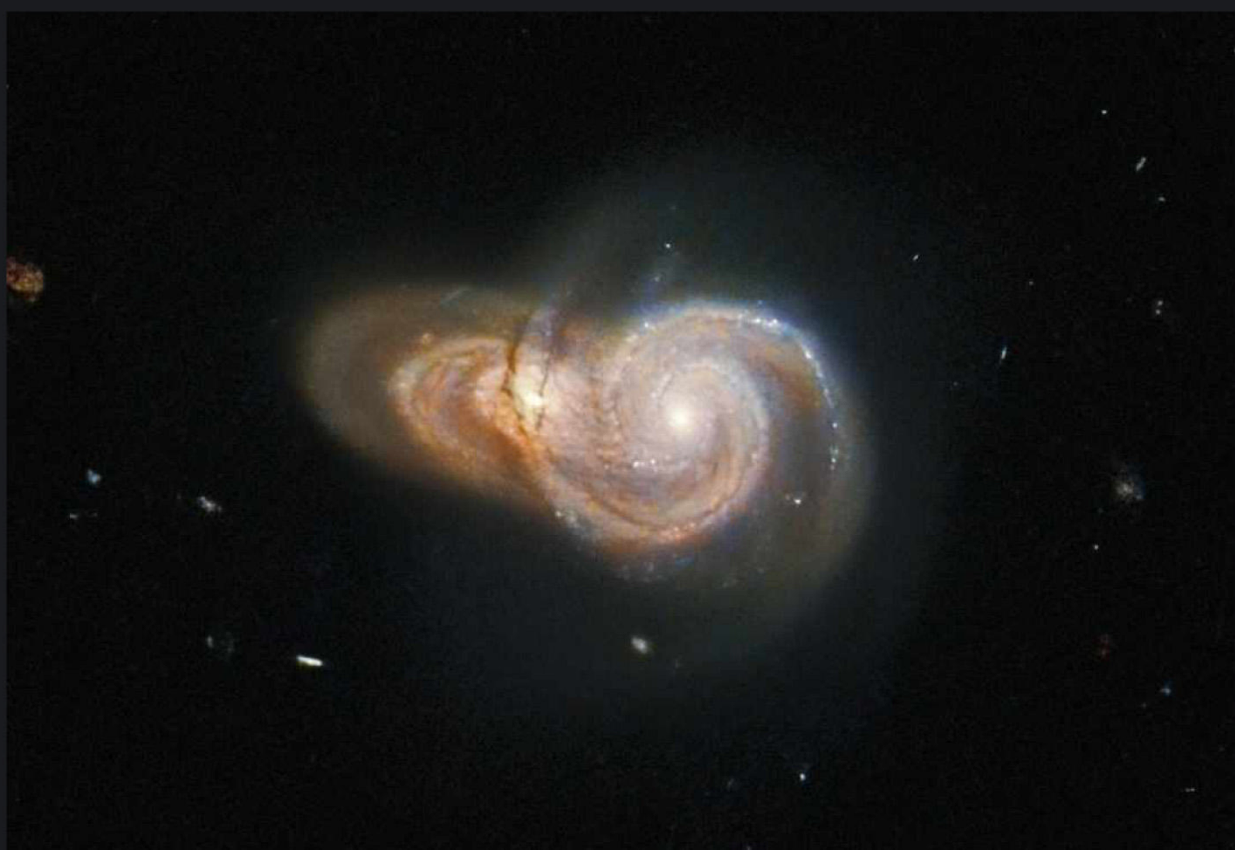
JAMES WEBB SPACE TELESCOPE, 6 SEPTEMBER 2022

Two views of the Tarantula Nebula in the Large Magellanic Cloud as never seen before. The image above used Webb's near-infrared camera (NIRcam) to show the star-forming region and its abundant protostars, uncovering spectral data that can reveal the age of the nebula and how many generations of star birth it has seen. On the left, Webb's mid-infrared MIRI instrument shows glowing gas and dust, blue hydrocarbons prominent, lit by energetic stars.

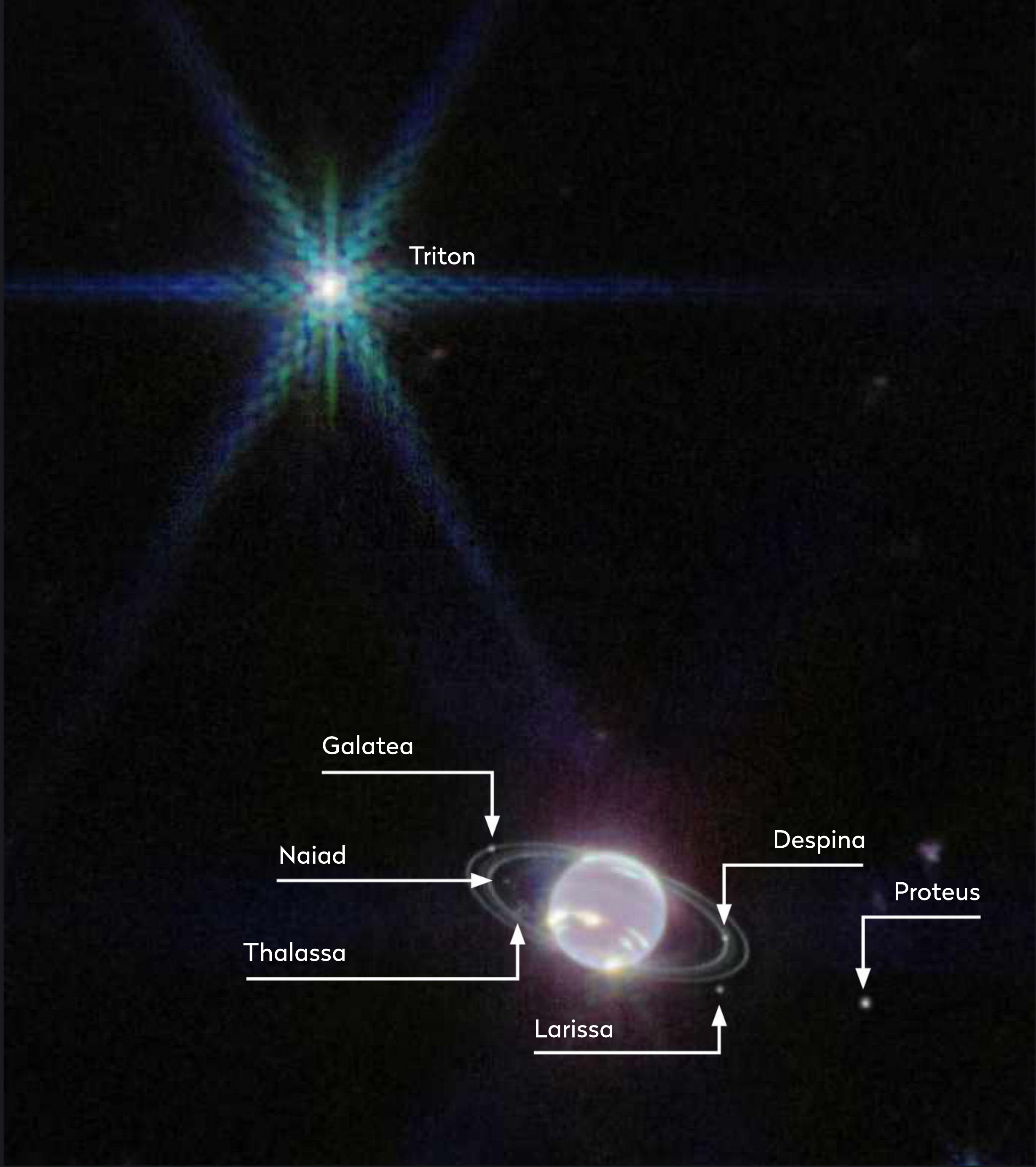
Galactic overlap ▷

HUBBLE SPACE TELESCOPE, 5 SEPTEMBER 2022

SDSS J115331 and LEDA 2073461 may not sound very exciting, but the identification of these galaxies certainly was. The remarkable overlap of these spirals was first spotted in Hubble data by volunteers from the Galaxy Zoo project. The telescope was then sent back for a better look, resulting in this image. Both galaxies are over a billion lightyears from Earth, and nowhere near each other, but the coincidental alignment certainly makes for an arresting image.



NASA/ESA/CSA/STSCI/WEBB ERO PRODUCTION TEAM X 2, ESA/HUBBLE & NASA/W. KEEL, NASA/ESA/CSA/STSCI, NASA/JOHNS HOPKINS APL X 4



◁ The rings of Neptune

JAMES WEBB SPACE TELESCOPE, 21 SEPTEMBER 2022

Neptune doesn't get a lot of love, but who could resist those rings? This image, another from Webb's NIRCam instrument, picks up the faint, dusty encircling system, some of which has gone unseen since Voyager 2 passed by in 1989. Also in the image are the large moon Triton and six smaller satellites, which adds up to half of the ice giant's 14 known companions.

▽ Brace for impact

DART, 26 SEPTEMBER 2022

NASA's Double Asteroid Redirection Test (DART) probe smashed into Dimorphos, the moonlet of asteroid Didymos, at the end of September, to test whether dangerous-looking asteroids or comets could be similarly deflected from Earth in the future. In its dying seconds, DART sent back these images. Dimorphos is silicate in nature and the impact produced a cloud of ejecta now being studied using ground- and space-based telescopes. Turn to page 11 to read more about the aims of the DART mission.


Passing Didymos, with Dimorphos 920km away


Approaching the moonlet, travelling at 22,530km/h


Three seconds and 18km from impact


The last complete image, 12km and two seconds before the probe's destruction

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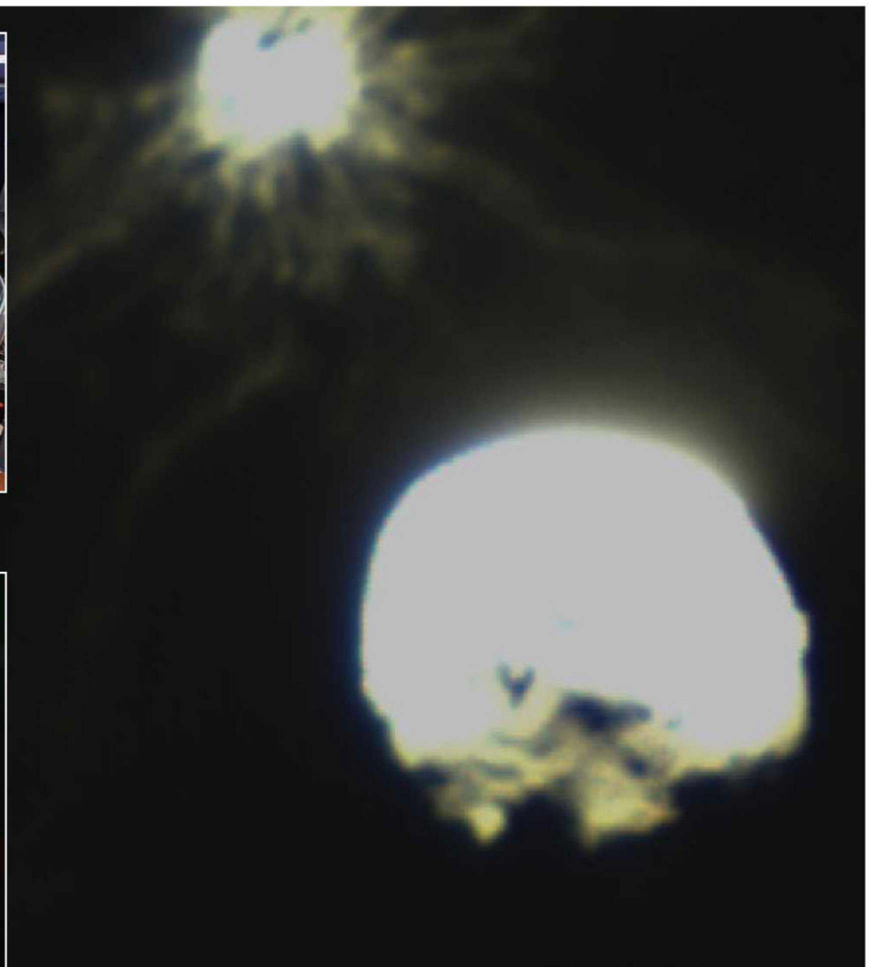
▲ The DART team celebrate the impact

▲ Chile's SOAR telescope captured this 10,000km trail of debris streaming from the distant moonlet



Clouds of ejecta spray from Dimorphos after the strike, as seen by the Italian Space Agency's LICIACube

DART successfully impacts asteroid

NASA's planetary defence strategy takes a step forward

Could humanity save itself from a killer asteroid? On 26 September, the Double Asteroid Redirection Test (DART) mission took us one step closer to taking on the challenge when it slammed into space rock Dimorphos at a speed of 22,530km/h (over 6km/s). Confirmation of the impact reached Earth at 7:14pm EDT (11:14pm UT), when the signal cut out halfway through sending back its final image.

Launched on 24 November 2021, DART's destination was Dimorphos, a 160-metre-wide 'moon' orbiting the larger Didymos. Though DART's camera was only able to target Dimorphos in the last hour of its mission, it transmitted images of its journey right up until the last moment.

"As we were getting close there was both joy and terror," said Elena Adams, DART's systems engineer. "We had no idea what to expect – we didn't even know what shape the asteroid was."

The impact was also witnessed by Italy's asteroid-imaging spacecraft LICIACube, which flew past Dimorphos about three minutes later and captured the cloud of ejecta thrown up by the impact.

The goal is to shorten Dimorphos's orbit around Didymos, currently 11 hours 55 minutes, by around 10 minutes. Given enough time, even a change that small could alter the path of an asteroid on a collision course with Earth, should one ever be discovered. Over the next two months, ground and space observatories, including the James Webb Space Telescope, will scrutinise the system to confirm how much its orbit has changed.

"As far as we can tell, our first planetary defence test was a success," said Adams. "Earthlings should sleep a little better. I definitely will."

dart.jhuapl.edu

Turn to page 9 to see more images from DART's last moments.

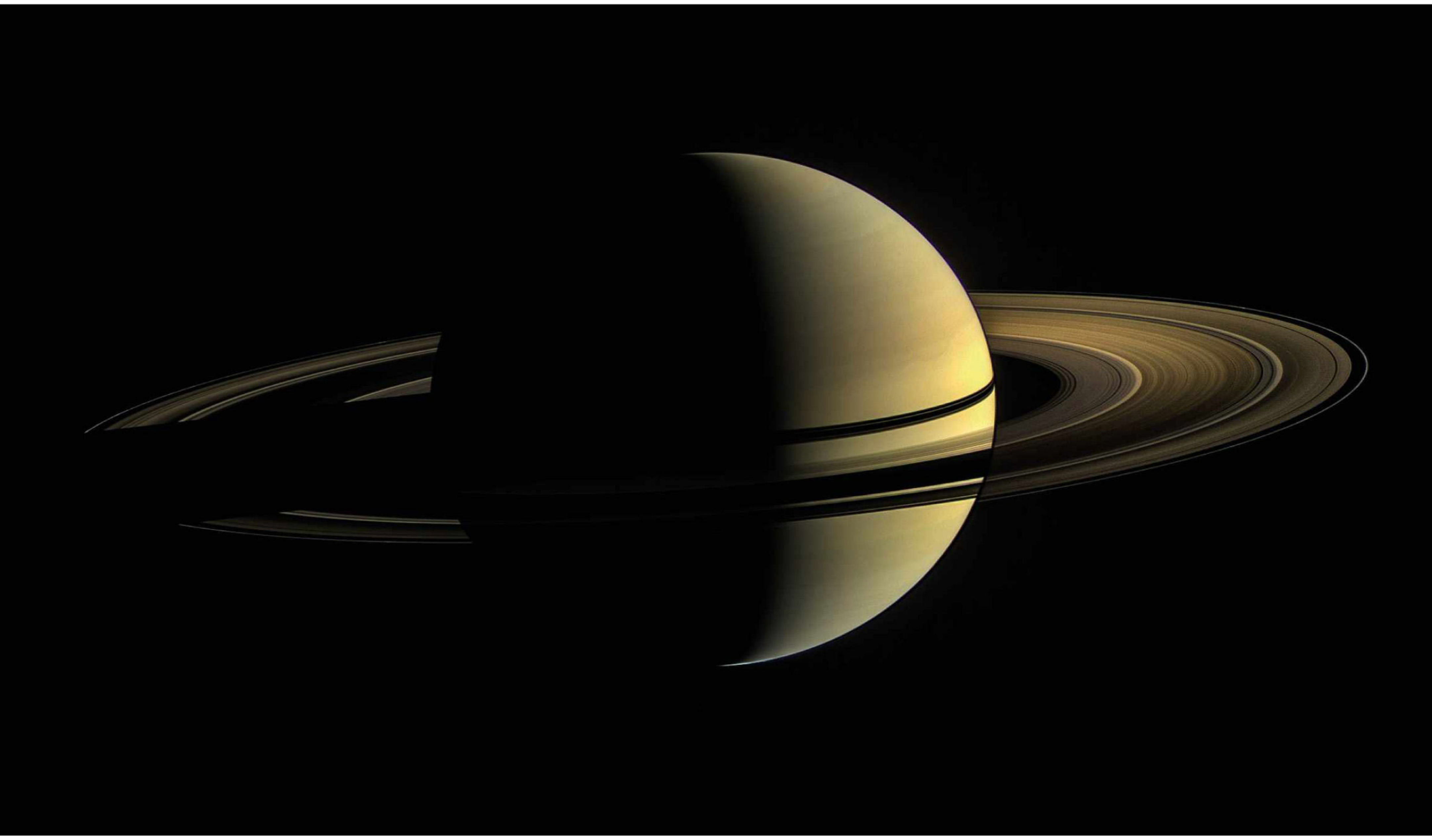
Comment

by Chris Lintott

Back in 2005, I watched from Palomar Observatory as the Deep Impact spacecraft collided with comet Tempel 1. Despite widespread excitement, the mighty 200-inch telescope saw nothing at all. This time, it was the other way round. No one expected to see much, but even small back-garden telescopes could see the asteroid brightening, while larger telescopes saw a cloud of debris thrown up by the impact. If DART had a bigger effect than expected, it confirms the impression that Dimorphos is more like a pile of rubble than a solid rock. Whether DART succeeded in changing the asteroid's orbit or not, we've learnt much already from its spectacular end.

Chris Lintott co-presents *The Sky at Night*

ASI/NASA, NASA/DAVID C. BOWMAN, CTIO/NOIRLAB/SOAR/NSF/AURA/T. KARETA (LOWELL OBSERVATORY), M. KNIGHT (US NAVAL ACADEMY)



▲ **Saturn's trademark rings could be the rubble of a moon wrecked 160 million years ago, leaving the planet with its distinctive lean**

The missing moon of Saturn

The moon could explain two of the planet's biggest mysteries – its tilt and its rings

It sounds like the premise for a science fiction novel, but Saturn could have a long-lost moon. The moon, called Chrysalis by researchers, may have broken apart 160 million years ago to create the planet's majestic rings.

"Just like a butterfly's chrysalis, this satellite was long-dormant and suddenly became active, and the rings emerged," says Jack Wisdom from MIT, who led the study.

The origin of Saturn's rings has been a long-standing question in planetary science. Over the last decade, there has been mounting evidence that the rings are a lot younger than the planet and have potentially only existed for 100 million years or so. The reason we can see them so well from Earth is because the planet is at a 26.7° angle. This tilt is thought to be due to a gravitational tug-of-war between Saturn and its neighbour Neptune, called a resonance. To be sure, however, requires knowing how Saturn's mass is distributed – something that the planet's rings make very difficult to measure. It was only when NASA's Cassini spacecraft flew between the rings and the planet during its Grand Finale in 2017 that the measurement could be taken.

With this in hand, researchers soon realised that Saturn was in reality just outside a resonance with Neptune – as if they had previously been in sync but were no longer. Wisdom's team set out to find what could have pushed the two out of step, first suspecting one of Saturn's 83 moons. Computer simulations showed this wasn't the case, but did reveal that removing a moon changed Saturn's tilt.

They then began investigating to see the effect of a lost moon, which was how they discovered Chrysalis. Initially about the size of Iapetus, Saturn's current third-largest moon, Chrysalis would have become gravitationally unstable around 100 to 200 million years ago. Once it strayed too close to Saturn, the planet's gravity would rip the moon apart, creating icy debris that went on to form the rings.

"It's a pretty good story, but like any other result it will have to be examined by others," says Wisdom. "But it seems that this lost satellite was just a chrysalis waiting to have its instability."
www.mit.edu

NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE, NASA/JOEL KOWSKY, NASA/ESA/CSA/A CARTER (UCSC) THE ERS 1386 TEAM AND A. PAGAN (STSCI), GEMINI OBSERVATORY/ARTWORK BY LYNETTE COOK.

Artemis I is rolled to safety as Hurricane Ian approaches

Artemis I returns to VAB again

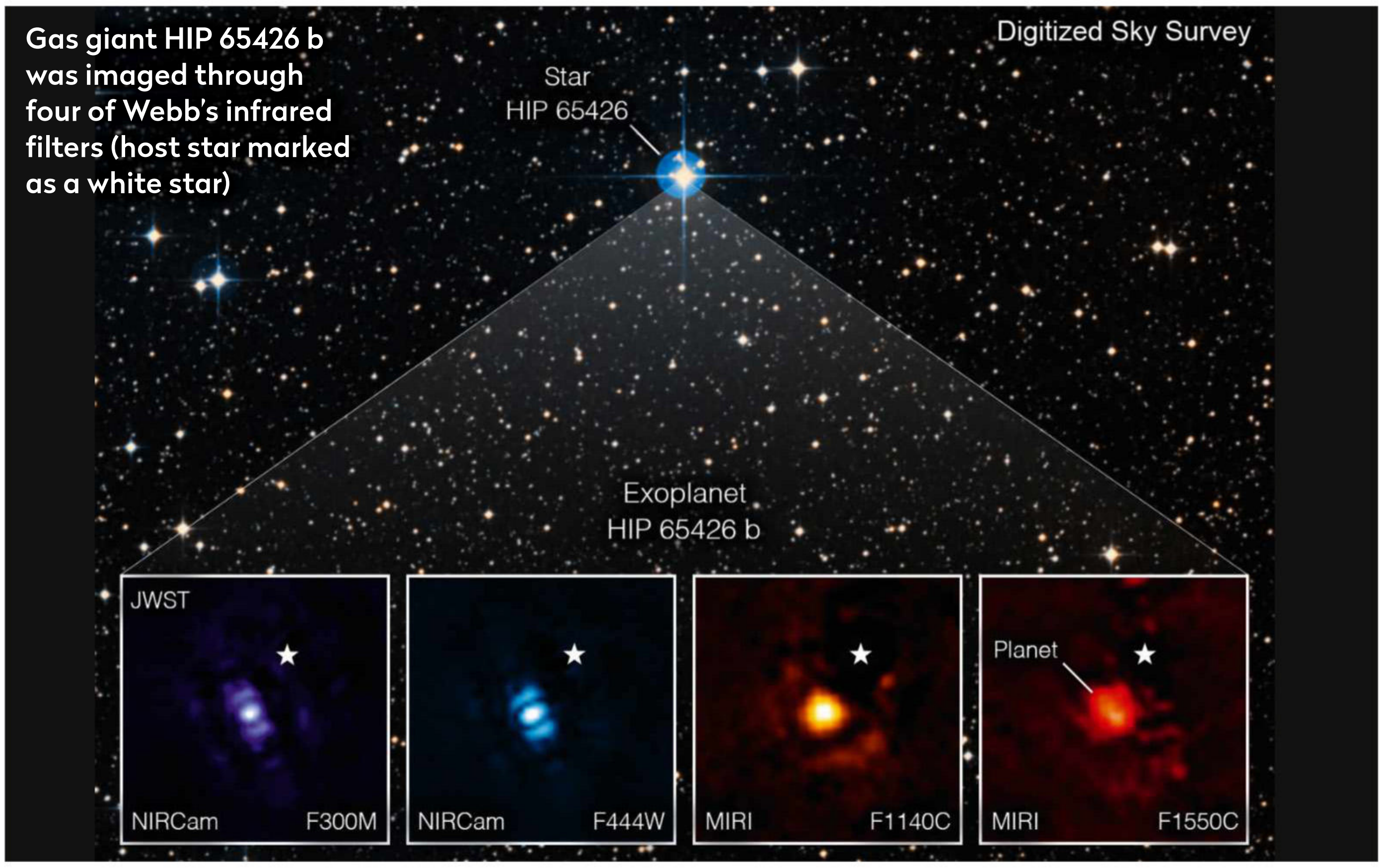
It was sheltering from a storm, but snags continue to plague mission

Stormy times continue for Artemis I after NASA returned the rocket to the Vehicle Assembly Building (VAB) on 26 September to protect it from Hurricane Ian.

The Artemis I mission is an uncrewed test of the Space Launch System rocket and Orion crew capsule that will return humans to the Moon for the first time in 50 years, but has been beset by problems. It has been returned to the VAB once already in April for repairs, then its first launch attempt on 29 August was called off due to an engine problem. Issues with the fuel lines delayed subsequent attempts.

NASA will use the roll-back as a chance to investigate these issues, as well as resetting batteries with expired flight certifications. At the time of writing, the launch will be occurring no sooner than mid-November. **www.nasa.gov**

JWST takes its first direct exoplanet image



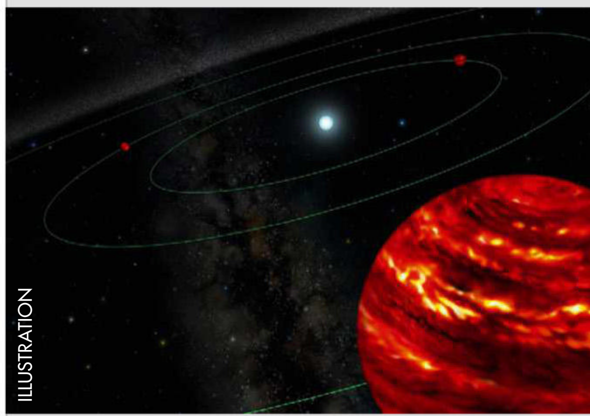
Gas giant HIP 65426 b was imaged through four of Webb's infrared filters (host star marked as a white star)

The James Webb Space Telescope (JWST) has released its first ever direct image of an exoplanet. The planet, HIP 65426 b, is a gas giant that's a youthful 15–20 million years old.

As a high-resolution infrared telescope, JWST can directly image exoplanets with relative ease. Planets appear brighter at infrared wavelengths than in visual light, while stars are dimmer. This makes a significant difference even though the star is still 10,000 times brighter than the planet. JWST used a set of masks, called a coronagraph, to block out the star, while still letting through the light from the planet orbiting 100 times further out than Earth does from the Sun.

"I think what's most exciting is that we've only just begun," says Aarynn Carter from the University of California, Santa Cruz. "There are many more images of exoplanets to come that will shape our overall understanding of their physics, chemistry and formation. We may even discover previously unknown planets too." **webb.nasa.gov**

NEWS IN BRIEF



ILLUSTRATION

Help confirm exoplanets

The SETI Institute and Unistellar Optics are asking back-garden astronomers and citizen scientists to help confirm exoplanet candidates found by NASA's TESS mission. Visit **science.unistellaroptics.com** to find out how you can use your eVscope or other telescope to help characterise new worlds.

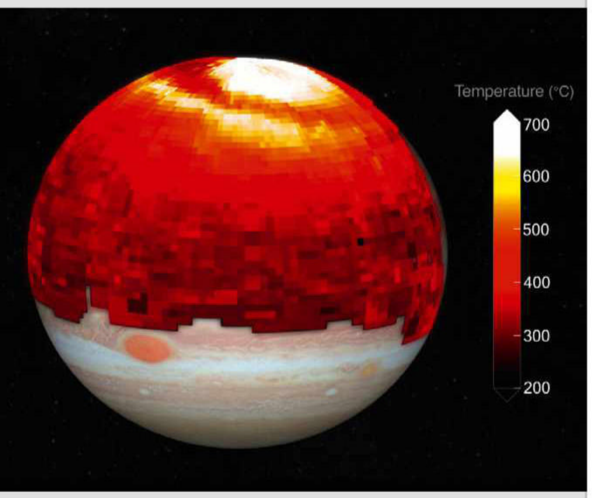
Small nursery, big planet

Thin planetary nurseries lead to a glut of large worlds. A new study has shown that if the gas and dust disc around a young star is super-thin, the dust settles into dense regions at its centre. This makes the grains clump together faster, leading to a higher portion of big planets.

MOXIE breathes easy

The MOXIE experiment on board the Perseverance rover has successfully generated breathable oxygen from Mars's thin atmosphere, it's been confirmed. A potential prototype for future life support systems, MOXIE created as much oxygen as a single modest tree during both the day and night, and across different Martian seasons.

NEWS IN BRIEF



Rising temperatures on Jupiter

'Heat waves' of 700°C have been discovered extending 130,000km (about 10 Earth diameters) above Jupiter's atmosphere. They are thought to be trigged by pulses of intense solar wind plasma hitting Jupiter's magnetic field, causing aurorae that deliver heat into the atmosphere. The hot gas then expands, spilling out across the planet.

Space Debate in UAE

The United Arab Emirates is hosting its first ever Space Debate in Abu Dhabi on 5–6 December. The event will gather leaders in spaceflight together to define the future of space and address the industry's most pressing challenges.

Pale brown dot?

Earth's 'pale blue dot' might be a rarity, if new simulations are to be believed. Looking into how the geological cycle shapes terrestrial planets, these suggest most rocky worlds would be almost entirely covered in land, 20 per cent would be mostly water, and less than one per cent would have an Earth-like balance of both.

HUBBLE/NASA/ESA/A. SIMON (NASA GSFC)/J. SCHMIDT/JAMES O'DONOGHUE, NASA/ESA ANDI JAMES (STSCI), MASCOT/DLR/JAXA

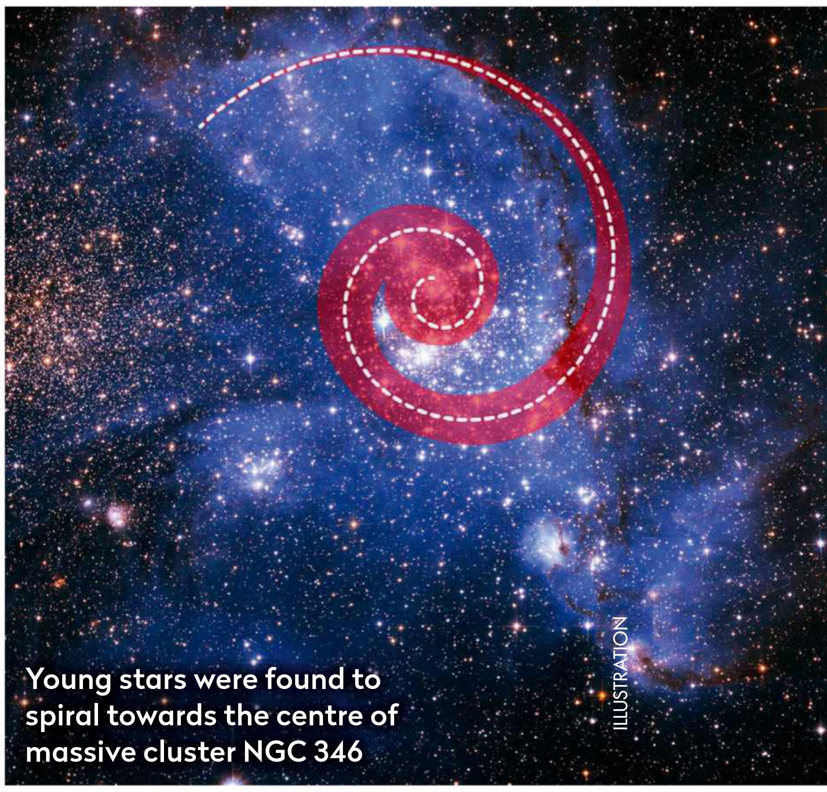
BULLETIN

Spiralling stars give window into early Universe

Swirling rivers of gas could create a boom in star formation

The spiral motion of stars inside a stellar nursery could help astronomers understand how star formation shaped the early Universe. Two new studies used 11 years of observations by Hubble and the Very Large Telescope in Chile to measure the motions of stars in stellar nursery NGC 346, located in the Small Magellenic Cloud. The region is poor in heavy elements, similar to galaxies from around two to three billion years after the Big Bang, making it an excellent proxy for studying these systems.

"A spiral is really the good, natural way to feed star formation from the outside toward the centre of the cluster," says Peter Zeidler from the Space Telescope Science Institute, who led the VLT observations. "It's the most efficient way that stars and gas fuelling more star formation can move towards the centre."
hubblesite.org



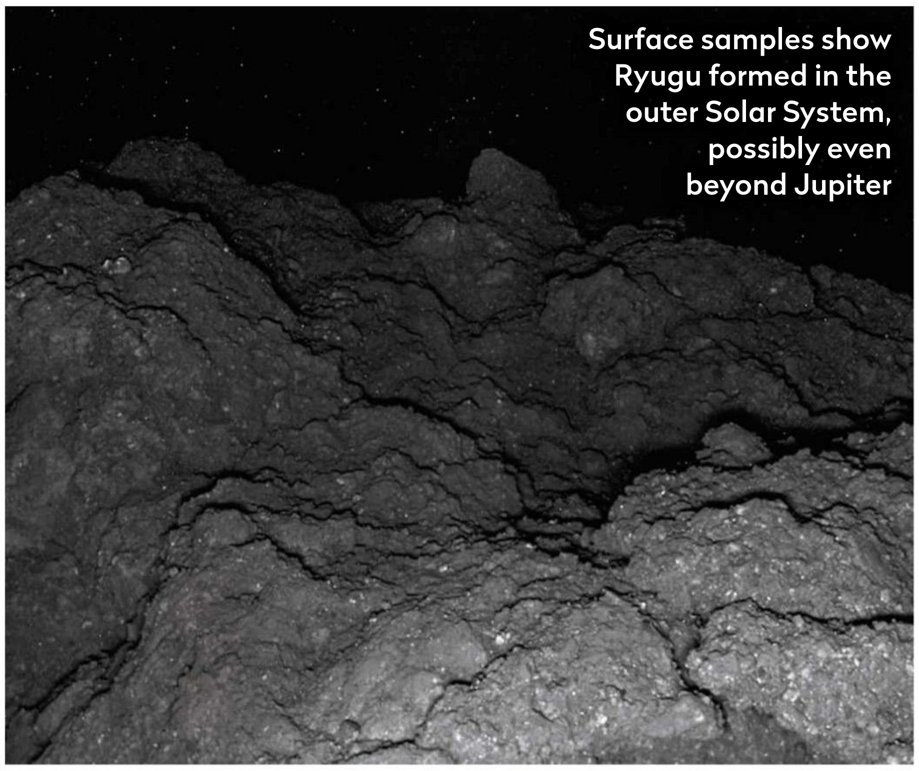
Young stars were found to spiral towards the centre of massive cluster NGC 346

Asteroid Ryugu had distant beginnings

The first analysis of samples brought back to Earth from the asteroid Ryugu have now been completed, showing the space rock probably began its life much further out in the cold, dark reaches of the Solar System.

In 2019, the Japanese spacecraft Hayabusa2 took surface samples from Ryugu, returning them to Earth in 2020 to be examined by eager researchers around the world. These preliminary tests found the dust contained water laced with carbon dioxide. This could only happen if both substances were solid when the asteroid body formed, meaning its original orbit was three to four times the Earth–Sun distance; that's twice as far out as it is now.

"The mineralogy of the Ryugu samples is similar to CI chondrites, a carbon-rich meteorite collected here on Earth," says Deborah Domingue, from the Planetary Science Institute, who took part in the study. Meteorites are our most easily accessible samples of asteroid material here on Earth, but their source is often unknown. "Understanding the formation history of Ryugu has real implications for understanding the origin of these meteorites and where their parent bodies formed in our Solar System."
www.psi.edu/news/analysisruygusamples


Surface samples show Ryugu formed in the outer Solar System, possibly even beyond Jupiter

Our experts examine the hottest new research

CUTTING EDGE

Nine Starlink satellites captured in a single nine-minute exposure of skies over north London

Starlinks still shine bright

Few solutions for the impact that Space X's mega-constellation has on astronomers

Starlink is a constellation of satellites developed by Space Exploration Technologies Corp, aka SpaceX. As of July this year, over 2,700 Starlink satellites have been launched, with the aim of ultimately providing global internet coverage via tens of thousands of satellites. To put this into perspective, there are less than 5,000 active satellites currently orbiting Earth. Starlink already provides the only viable access to the internet for many remote parts of the world.

While it is an admirable venture to connect the world to this marvellous network of human communication, it hasn't come without criticism, including from astronomers.

Part of the problem is the Starlink satellites are positioned in low-Earth orbit, so appear particularly bright and move rapidly across the night sky. With the sheer numbers shooting across the heavens, the concern is that they can severely disrupt ground-based astronomy, ruining an image or spectroscopic measurement as they streak through the telescope's field of view. SpaceX attempted to minimise this light pollution by coating one of the Starlink satellites with a dark material – creating 'DarkSat' – but this caused problems with controlling its temperature. So in August 2020 SpaceX switched to launching 'VisorSat' Starlinks equipped with a sun visor to reduce the glare of sunlight reflected back to Earth.

Just how bright are they?

What's been relatively uncertain until now, however, is exactly how bright the Starlink satellites appear in the night sky, and how accurately their positions are known, which is why Vishnu Reddy from the University of Arizona asked student Grace Halferty to investigate the problem as an undergraduate project.

The team imaged Starlink passes using a widefield lens with a field of view 15 times larger than the width of the full Moon, fitted to a 16-megapixel camera. They collected over 350 observations of 61 Starlink satellites over a four-month period from February 2021, and calculated the brightness of each using the known magnitude of stars in the same frame.

They found that the average magnitude of the first generation of Starlink satellites was +5.1. The magnitude of the DarkSat averaged +7.3 – almost eight times fainter than the earlier Starlinks – but the VisorSats only reduced the glare by 2.3 times to a magnitude of +6.0. They concluded that this generation of VisorSats were so bright that they posed a significant hindrance to astronomers.

"They concluded that this generation of VisorSat Starlinks were so bright that they posed a significant hindrance to astronomers."

One strategy proposed to avoid the problems of Starlink trails is to temporarily close telescope shutters for 10 seconds while a Starlink satellite crosses the frame, but this relies on precise knowledge of when these occur. So the team also checked the accuracy of the predicted Starlink positions in their orbits. They found an average time difference between the published and observed position along their orbit of 0.3 seconds, meaning that such observational pauses are likely to be effective.

This at least offers a workaround solution to the light pollution from the satellite mega-constellation. But what stood out for me was how it was a great example of how undergraduate student projects can create useful scientific knowledge.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Photometric Characterization and Trajectory Accuracy of Starlink Satellites: Implications for Ground-Based Astronomical Surveys* by Grace Halferty et al.
Read it online at: arxiv.org/abs/2208.03226

STEPHEN CHUNG/ALAMY STOCK PHOTO, NASA/ESA/HUBBLE/MELI THEV

A galaxy full of Orions

A distant galaxy discovered by *Stargazing Live* viewers turns out to be a key to the early Universe

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

For years, I got to work on *Stargazing Live*, enabling the large audience assembled by Brian Cox and Dara O'Briain to contribute to science via their web browsers. Working with the fabulous Zooniverse team, over the years we looked for exoplanets, for strange 'spider' features on Mars and even measured the age of the Universe by finding supernovae. But the most fun I had was looking for gravitational lenses in 2014.

The goal was to find the images of distant galaxies that have been deformed, and most likely magnified, as their light passes by nearby massive systems such as other galaxies and clusters. The gravity of these nearer systems bends the incoming light and, if things line up just right, the images end up looking like little blue rings or arcs that we can use to get information about the distant Universe. Over three consecutive nights, *Stargazing Live* asked its viewers to look through millions of images taken by the Dark Energy Survey to identify potential lenses. By lunchtime the day after the first show, we thought we had a good candidate in the form of a ring. It wasn't blue, but red, but it definitely looked like a bona fide lens: the catchily named 9io9.

'Maybe' wasn't good enough for Brian or his producers, though. We needed a radio telescope to confirm the discovery, and so viewers on the show's second evening saw the Lowell telescope in Arizona taking data confirming galaxy 9io9 was a distant system. The light reaching us today set off 11 billion years ago, when the Universe was just 2.5 billion years old.

A factory of stars

Since the discovery, a team led by Jim Geach at the University of Hertfordshire has been observing the galaxy, finding that it is a remarkably efficient factory of stars. But how do galaxies undergoing extreme star formation in the early Universe behave? Recently they've being using ALMA, a sub-millimetre array situated on the high, dry Atacama Desert in Chile, capable of detecting faint radiation from molecules such as carbon dioxide and ammonia. These typically exist in the dense gas associated with star-forming regions, where they get excited and shine in the wavelengths ALMA looks at. It seems, from the observations, that ammonia and hence star formation is spread throughout the galaxy's disc, rather than concentrated in one particular region.

"It seems ammonia and hence star formation is spread throughout the galaxy's disc. That settles a long-running argument"

If 9io9 is typical, that settles a long-running argument about these extreme star-forming galaxies. Some thought such prodigious feats of star formation would only be possible if concentrated into a single massive complex, perhaps at the galaxy's centre – but instead the whole galaxy seems alive with newly forming stars. Its properties, and in particular the strength of the emissions from ammonia and carbon dioxide, look rather similar to those in our own local stellar nursery, the Orion Nebula.

It turns out that what *Stargazing Live* viewers found is what Matus Rybak, a PhD student in Garching, Germany, described as a galaxy "full of Orions". Each of them, the authors say, might be individually unremarkable, but they add up to a galaxy the likes of which transformed how the Universe looked. Almost as remarkable, a discovery made collectively by thousands of viewers watching TV on a cold January night eight years ago continues to expand our knowledge of that distant and ancient cosmos.

Gravitationally-lensed galaxy 9io9, discovered by TV viewers and wowing scientists ever since

Chris Lintott was reading… *Ammonia in the Interstellar Medium of a Star-Bursting Disc at z=2.6* by M J Doherty et al.
Read it online at: arxiv.org/abs/2209.09268

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

▲ From left, Nial and other guests on the expert panel, Chris Lintott, Pete Lawrence, Maggie Aderin-Pocock and Suzie Imber, fielded viewers' questions asked by host Dallas Campbell, on everything from space junk to dark matter in the Q&A special

October's *Sky at Night* was a Q&A special. Panel member **Nial Tanvir** tells us five questions he's frequently asked about cosmic explosions

My research mainly focuses on transient phenomena that come and go, particularly extremely powerful explosions known as gamma-ray bursts (GRBs). Some of these are produced by the deaths of massive stars, while others are from the mergers of binary neutron stars. The five questions I'm always asked about my research are:

Have astronomers looked for the place that the Big Bang occurred?
The surprising thing we find, looking far across the Universe, is we essentially see a similar distribution of galaxies in every direction. There's no special place that could represent the centre of the Universe. In fact, this is built into the foundations of the Big Bang theory, which starts by assuming a symmetrical Universe. It also assumes it is infinite, meaning there is no centre and every point has essentially the same experience. The Big Bang isn't an explosion in space, but more an explosion of space.

Aren't some galaxies moving away faster than the speed of light, in contradiction of the theory of relativity?
It depends on how one defines distance and time. It is true that under certain ways of looking at distance, faraway galaxies are receding from us faster than the speed of light, breaking the cosmic speed limit. But if we regard that as the space between us and the distant galaxy expanding faster than the speed of light, then nothing is moving faster than the speed limit relative to other matter in its vicinity.

How can we see GRBs from 13 billion years ago? Wouldn't their light have long passed us by now?
It's a very good question and one of those aspects of the Big Bang theory that challenges our intuition. We already said the space between us and distant galaxies is expanding, so the light from them is continually playing catch-up in its journey from there to here. This means that some of the light is only just reaching us, and we see distant objects as they were in early times in the Universe.

BBC, NRAO, XUANYU HAN/GETTY IMAGES

Nial Tanvir is a professor in astronomy and physics at the University of Leicester

If the creation of black holes creates GRBs, why are they bright explosions? Shouldn't everything just fall in the black hole?
When a large enough star collapses, it is initially just the central core that forms the black hole. The hole is only a few miles across (compared to millions of miles for the star). Gravity will cause material to fall into it, but the star's rotation will initially cause it to miss and be drawn into a disc around it. In the process, the potential energy of the matter gets transformed into heat, rotational velocity, magnetic energy, and so on. The surprising thing is that a fair fraction of this energy goes into powering very fast-moving jets or beams of outflowing plasma, and it is these that create gamma-ray bursts. Exactly how this occurs is still being researched, but it's probably the result of the star's magnetic field being wound up like a rubber band, throwing out matter when it unwinds.

Could GRBs affect us on the Earth?
GRBs are so powerful they could pose a threat to life on Earth if one occurred in the Milky Way. Fortunately they are very rare, even rarer in galaxies like ours. In practice they're not a great risk, but it's still important that we improve our understanding of them, to identify potentially threatening systems nearby.

Looking back: The Sky at Night

10 November 1986

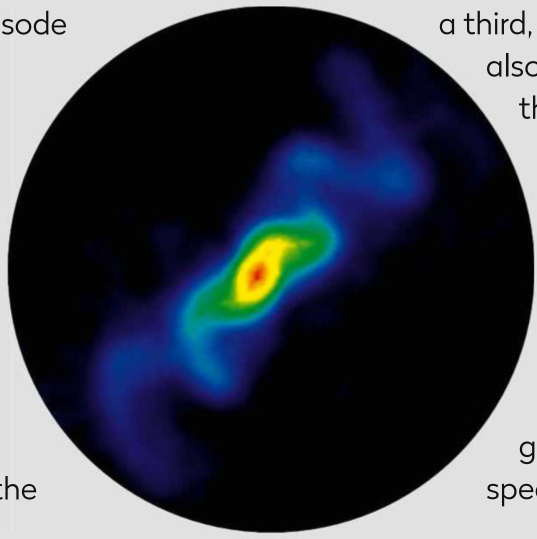
In November 1986's episode of *The Sky at Night*, Patrick Moore took a look at one of the most bizarre stars ever observed: SS 433, 18,000 lightyears away in Cygnus.

It first rose to prominence in 1978, when astronomers at the Anglo-Australian Observatory found a star that had a pair of emission lines, one of which was blueshifted, meaning it was coming towards us, and another that was redshifted as it moved away, leading it to be dubbed 'the star that's both coming and going'.

The more astronomers observed the star, the stranger it got. The lines were soon found to be shifting back and forth in wavelength, crossing over each other and back again in a 160-day cycle. Soon a third, stationary line was also discovered, showing the lines were coming from hydrogen gas, but behaving very strangely.

It turned out that the star was spinning like a top, while firing out two huge jets of gas at a quarter the speed of light. When a jet pointed at Earth, it was bluer; as it tipped away, it became redder.

The relativistic speeds meant the light was also experiencing time-dilation effects, making it look even weirder. Those effects are usually only seen around black holes, leading to the discovery that SS 433 is actually a binary system, the larger star having collapsed in the stellar mass black hole. As it feeds off its orbiting companion, it throws off the huge jets.



▲ **Corkscrewing jets fire from SS 433, one of the weirdest stars ever found**

The Multiverse of Mystery

In this month's episode, Maggie and Chris delve into the biggest astronomical mysteries that are yet to be solved. Do multiple universes exist? Will interstellar travel ever be possible? Are white holes only a theoretical concept or are they a reality? Join the team as they explore these and other fantastical questions in the final *Sky at Night* episode of 2022.

BBC Four, **14 November,** 10pm (first repeat will be on BBC Four, **16 November,** time tbc)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ **Could white holes really exist or are they science fiction? *The Sky at Night* finds out**

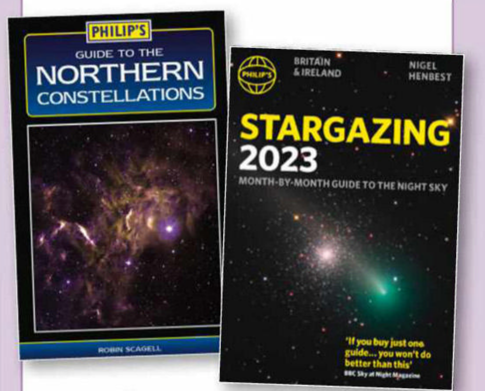
Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: two Philip's titles



The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2023* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

The excitement is building

My son Jack is fascinated by all things space. He was delighted to receive this Lego Creator NASA Apollo 11 Lunar Lander set for Christmas from his grandparents. We decided to tackle this challenging build during the summer holidays, when we'd have the time to dedicate to each of the sections. It took us over four weeks to build and Jack did a fantastic job as it's aimed at 16-year-olds upwards and he's seven! The detail is fantastic. We really enjoyed talking about the lunar module's features and all of its accessories. Inside the module there is a detailed interior with room for two astronauts. Our summer Lego build happened to coincide with the [planned] Artemis I launch, which Jack took great interest in!

Claire Moore, Bristol

It's wonderful to see such an avid young space fan as Jack, Claire! I'm sure he's anticipating Artemis I's launch as much as we are. ***– Ed.***

▲ **Proud Lego architect Jack with his Apollo lander**

Tweet

Sue Robinson
@suerobphoto • 28 Aug

My last night cat-sitting on the outskirts of London. Couldn't resist the sky, even though I knew there'd be aircraft trails. This was just 2 hours' worth. #Jupiter is the bright, thickest line bottom right, disappearing behind a tree and phone mast. #space #startrails #colours

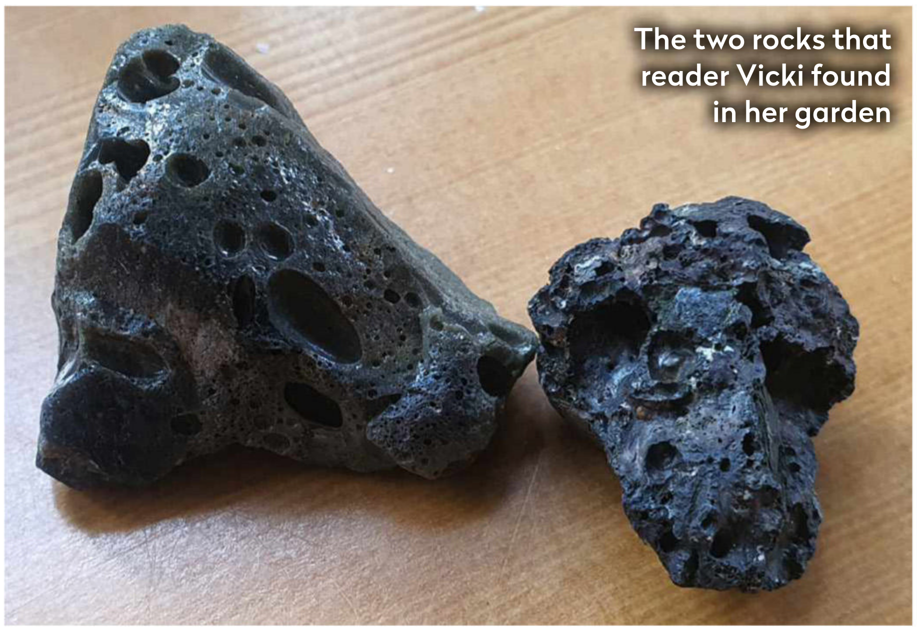
Moon-bound tribute

I'm a physicist, astronomer and science communicator from Ireland and I had the good fortune of meeting Sir Patrick Moore over the years. About 12 years ago he even phoned to congratulate me when I had my science book *Mars: A Cosmic Stepping Stone* published. Back in March this year I added Sir Patrick Moore's name, as well as Sir Isaac Newton's, to the NASA portal for name submissions for the Artemis I mission. I thought perhaps nobody else might do it, and how appropriate it was for both Newton and Moore to be included in this first opportunity to send names to the Moon. Their NASA boarding passes will fly around the Moon with Artemis I when it launches.

Kevin Nolan, Dublin

Catch the ISS

My wife Lindsey and I are keen sailors and recently undertook a 6,500km voyage from Panama to the Marquesas Islands in French Polynesia. While we were in the middle of the Pacific Ocean I was musing that the nearest person to us was in fact an astronaut on the ISS, as we were also outside normal shipping lanes. On checking the historical path of the Space Station I think this may well be true, as the ISS is only about 400km above Earth. Similar musings left me thinking that



The two rocks that reader Vicki found in her garden

there were points on Earth that no one in history had ever sailed over, based on passages since 1800s. But a question which I hoped other readers might answer: if the ISS trailed a wire down to us on our boat while sailing, with a shielded weight on it, I assume the drag would pull it out of the sky, but how close would the space station get to our boat?
Andrew Snowdon, Great Yarmouth

Space rocks?

Could any other readers tell me if these two pieces of rock (above) are meteorites? I found them in my front garden the other day and as I clear the weeds regularly, I know they've only recently appeared. The larger piece is 3cm in length. If they did fall from space, luckily they missed my car, parked only about a metre away!
Vicki Moles, via email

The Milky Way on a smartphone

Mobile merits

I have been experimenting with my phone camera in pro mode outside at night, and at about 10pm on 21 September I was able to get this image of part of the Milky Way from our back garden. I had the phone secured by an adaptor to a tripod and I set the camera to ISO 1700 with a shutter speed of 10 seconds. I adjusted the settings and filters after the image was taken and I'm more than happy with the result. I am getting more into backyard astronomy and just wanted to encourage others to ▸

ON FACEBOOK

WE ASKED: What are the best things to observe on the Moon, and what are your tips for seeing them?

Debz Townsend I use my Celestron 81055 NexYZ smartphone adaptor attached to the eyepiece of my 8SE. I like to look at craters and I've even captured the Apollo landing site.

Eric Grieve Bay of Rainbows every time.

Mihai Saiph Aristarchus crater, Schröter's Valley and Clavius with its numerous craterlets inside. Bino viewing at 90–100x can be very addictive. For imaging a sharp 'mineral' Moon, a long-focal mosaic with a planetary camera (preferably mono), blended with a full-disc DSLR image (for the colour) gives awesome results.

Bill Watson Progressive shadows.

Carol Miller The Alpine Valley, Tycho and Copernicus. One top tip is to get familiar with the lunar phases so you know when to start observing, especially if using a telescope.

Darren Foy No Moon is a good Moon. I'm all for deep sky!

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

As a full-time wheelchair user, I find the eyepiece height on a refractor perfect. Now I'm looking for a more advanced, yet lightweight model. Do you have any suggestions?

ALUN WATSON

▲ StellaMira's relatively lightweight 110mm ED f/6 refractor could fit the bill

WWW.FIRSTLIGHTOPTICS.COM

As with any telescope choice, there is no one telescope that is ideal for all celestial objects, but as you are past the beginner's stage, and bearing in mind your wheelchair use, a refractor with an ED doublet lens would most likely be the most appropriate. A telescope like this will afford you excellent views of a wide range of objects, will cool down faster than a triplet lens and will help to keep the overall weight at manageable proportions.

Generally, for deep-sky observing the larger the aperture the better, so something in the 100mm to 120mm range would make most sense. The StellaMira 110mm ED f/6 refractor, with a focal length of 660mm and weighing in at just over 5kg, immediately springs to mind as it has an excellent ED doublet lens and a smoothly operating 2.7-inch dual-speed rack and pinion focuser. Also worth considering is the Altair Starwave 102ED FPL53 refractor, with a focal length of 714mm and weighing in at around 4kg.

Steve's top tip

What is a CMOS camera?

In an astro imaging context, CCD (charge-coupled device) camera sensors have been the sensor of choice for the long exposures required for capturing dim, deep-sky objects, as they produce a good signal-to-noise ratio and are easy to calibrate. CMOS (complementary metal–oxide–semiconductor) sensor cameras have been used in CCTV and DSLR cameras for many years where shorter exposures are normally used and the inherent 'noise' produced by the sensor is less intrusive. However, in recent years CMOS sensor technology has improved to the point where their sensitivity means that light from dim objects can be captured quickly, producing excellent images using shorter exposures.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

BBC Sky at Night Magazine is published by Our Media Ltd (an Immediate Group Company) under licence from BBC Studios, which helps fund new BBC programmes.

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SUBSCRIPTION RATES
Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

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abc Audit Bureau of Circulations
23,082 (combined; Jan–Dec 2021)

ISSN 1745-9869

IPAC/CALTECH BY THOMAS JARRE

Instagram

dane_1984 • 26 September

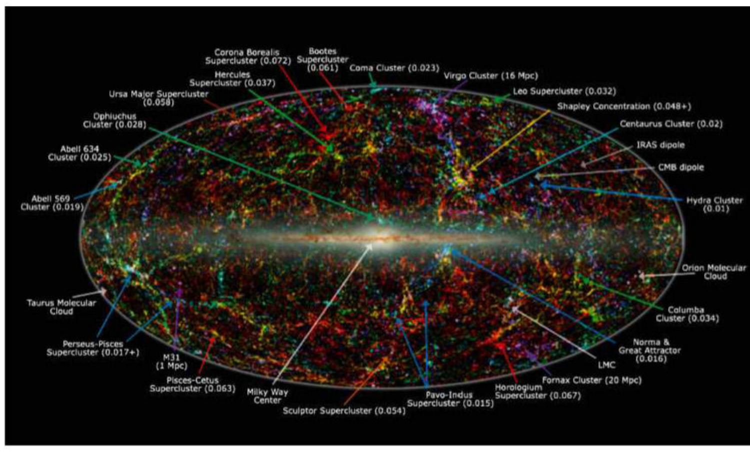
Jupiter with Europa and Io from last night. The seeing conditions were horrendous to begin with but luckily got a little better. #jupiter #planets #celestron #nexstar6se #televue #powermate #zwoasi224mc @bbcskyatnightmag @celestronuk @zwoasi @televueoptics

▸ take a look outside and capture a photo. It's amazing what you can get with today's smartphones.
Carol Miller, Lanivet, Cornwall

Where am I?

Where in the Universe is the Milky Way? I thought that it was in the Virgo Supercluster. However, I recently saw this diagram (right) which shows our Galaxy in the middle. Can you help?
Grant Ross, via email

You're right that on the largest of scales our Galaxy's location in the Universe is in the Virgo Supercluster, Grant. The diagram you saw, with the Milky Way in the middle, shows the whole of the sky from Earth, which explains why our home Galaxy is in the centre. It's a near-infrared view, so it reveals all the galaxies beyond our own, and they have been colour-coded by redshift, with blue closest and red furthest away. ***– Ed.***



▲ **The all-sky near-infrared view seen by reader Grant that puts us in the middle**

CORRECTIONS

The DIY paper sundial made by Akira Bartram, which was the Message of the Month in our September 2022 issue, was made together with her grandfather Peter Berkin, not Peter Bartram as printed.

SOCIETY IN FOCUS

Usk Astronomical Society meets regularly to observe the night sky and encourage the general public to enjoy the wonders of the cosmos. The society is over 40 years old and has about 30 members. Before the pandemic we met weekly, but that was reduced to fortnightly meetings online; we've since moved to hybrid meetings. We welcome speakers from the society and beyond, and have our own observatory with a 12-inch reflecting telescope.

We're heavily involved with outreach, visiting schools, museums, youth groups and events with our inflatable planetarium and telescopes. We work closely with Brecon Beacons Dark Sky Reserve and the Brecon Beacons National Park Authority, through which we recently acquired a new digital planetarium, which we put to good use at an outreach event this summer. In September 2022 we attended the Usk Show, a large country fair, and welcomed about 200 visitors to the planetarium throughout the day. We strongly promote messages around preserving dark skies and avoiding light pollution for the benefit of wildlife, the environment and human health. If you're based in the Usk area, feel free to get in touch and get involved!

▲ **Nick (far left) and Usk Astronomical Society members with the new inflatable planetarium they use for outreach events**

Nick Busby, Chairman, Usk Astronomical Society
▸ **www.uskastronomicalsociety.org.uk**

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

PICK OF THE MONTH

▲ See the world's finest astro photos at the National Maritime Museum exhibition

Astronomy Photographer of the Year 2022

National Maritime Museum, Greenwich, London, until August 2023

The annual showcase of the phenomenal talent in the world of night-sky photography returns to the National Maritime Museum, with the exhibition of the choice picks from the 2022 Astronomy Photographer of the Year competition. These include not just all the winning images, but also some of the best photos from the more than 3,000 entries received from 67 countries around the world. From planets, asteroids and aurorae to galaxies, our Sun, nebulae and so much more, you'll find out-of-this-world photos that will take your breath away. Running until next summer, tickets are £10 for adults, £6.50 for concessions, £5 for children. **www.rmg.co.uk/whats-on/astronomy-photographer-year**

Kelling Heath Winterfest

Kelling Heath Holiday Park, Norfolk, 24–28 November

Timed for the new Moon for the darkest skies, this relaxed star party organised by Birmingham Astronomical Society is purely an observing event without sales stalls.
www.kellingheath.co.uk

Stargazing weekend

Mungrisdale, Cumbria, 5 November

Get away from light pollution to the Lake District for a weekend hosted by astronomer Andy Gray, with opportunities for astrophotography and telescope tips. Tickets are £20 per adult, £12 per child and include hot drinks and biscuits.
www.nearhowe.co.uk/things-to-do/dark-skies

Stargazing at Mugdock

Mugdock Country Park, Glasgow, 8 November, 7pm

Stargazing at Mugdock returns for a new season of observing the night sky. This session is all about the wonder of the full Moon and what you can see through a telescope. Booking essential. Entry is £7.
www.mugdock-country-park.org.uk

Observing session

Lacock, Wiltshire, 18 November, 6:30pm

Join Wiltshire Astronomical Society in the Red Lion car park, Lacock, for their monthly observing session, with a backup date of 26 November if it's cloudy.
www.wasnet.org.uk/observing

Introduction to astronomy

Friends Meeting House, Derby, 18 November, 7:30pm

A beginners' session with Derby and District Astronomical Society, featuring advice on using telescopes, finding your way around the night sky, astrophotography and possibly some observing in the garden.
www.derbyastronomy.org

Stars and Stones

OM Dark Sky Park, County Tyrone, now until March

Northern Ireland's newest public observatory reveals the secrets of the Beaghmore Stone Circles, a neolithic gateway to the stars. For full details, visit **www.omdarksky.com/whats-on**

Telescope workshop

Deer Park Archers, Cheltenham, 27 November, 7pm

Learn how to set up or get the most from your telescope, and find out more about the activities of Cotswold Astronomical Society. Open to anyone with an interest in any area of astronomy.
www.cotswoldas.org.uk/our-events/observing

BRIAN BOGGENPOEL, NATIONAL MARITIME MUSEUM

The amateur astronomer's forum

FIELD OF VIEW

Dear diary...I saw fire in the sky

Jonathan Powell dusts off eye-witness stories of ancient astronomical events

XUETONG WANG/FOLIO

Jonathan Powell is a freelance writer and broadcaster. A former correspondent at BBC Radio Wales, he is currently astronomy columnist at the *South Wales Argus*

As those who regularly keep a diary will know, the contents can often be of a very personal nature, an outpouring of feelings and opinions that speak from the heart and are for the sole eyes of the author. But some journals are written for a different purpose and with a wider, more public, readership in mind. Whether they're for private or public perusal, diaries from the past have revealed fascinating insights into events in the sky, including many astronomical 'firsts'.

Not all diaries are handwritten. The remarkable astronomical chronicles of Mesopotamia were committed not to paper but stone, in cuneiform, a symbolic form of script. Indeed, possibly the earliest reliable account of the aurora borealis was discovered on one particular Mesopotamian clay tablet. The diary-like text made by official astronomers describes an unusual 'red glow' in the night sky during the 37th year of King Nebuchadnezzar II, the exact date of which relates to the night of 12/13 March 567 BC.

Closer to home, medieval monasteries were a rich source of astronomical diary entries. The earliest known sunspot record was discovered in the chronicle of John of Worcester, dated 8 December 1128. English monk Gervase of Canterbury witnessed Mars in conjunction with Jupiter on the night of 12 September 1170, "...to such a degree that it appeared as though they had been one and the same star". We know now that he had caught the last part of a rare transit and that the event was ending just as the planets were rising in the sky.

That was chalked down as one of the first western observational records of a planetary transit. It is also possible, from his description of "fire, hot coals and sparks...spewing out, over a considerable distance" from the lunar surface, that Gervase (along with others) witnessed the Moon being hit by an unknown body on the evening of 18 June 1178.

In the tumultuous 17th century, diarist John Evelyn wrote of the solar eclipse of 1652, where from London almost all the Sun's disc was obscured. Samuel Pepys started his famous diaries in 1660, just as England returned to having a monarchy with Charles II's restoration. Pepys had lived through Oliver Cromwell's rule, witnessed the Great Plague and the Great Fire of London, served as an MP and been locked in the Tower of London for treason. Among all that, he also wrote of astronomy and his passion for telescopes in his diaries. Several entries surround the 1664 comet that he observed that December, and there is a glorious description of a bright meteor, a "sudden fire running in the sky" he saw in 1668.

Lawrence of Arabia consulted the astronomical notes in his own diary when he reassured his troops that during a planned night attack there would be a lunar eclipse to baffle and confuse the enemy, which it duly did. Then there's Virginia Woolf's vivid and exquisite diary-like account of the total solar eclipse of 1927, which featured in her book, unsurprisingly called *The Eclipse*.

It appears that our some of our predecessors captured within their musings precious personalised glimpses of astronomical events in a way that perhaps, in our more clinical analysis of the skies today, is sadly missing.

A history of the Moon in EIGHT FEATURES

The Moon bears the scars of its long and violent past. Astronomer Will Gater looks at eight features that reflect its extraordinary history that you can see for yourself

Few objects in the Solar System record the remarkable history of our planetary neighbourhood more starkly than the Moon. Not only does it bear the scars of eons of impacts by asteroids and comets, but its very existence is testament to a cataclysmic collision that's thought to have forged the Earth we stand on today. When we gaze at the airless lunar surface, a barren landscape of deep shadows, shining mountain peaks and grey basalt plains, we can also reflect on our own small imprint, quite literally, on the cosmos. The footprints of humanity's first Solar System explorers remain there even to this day, and likely will do for millennia yet. In this feature, we highlight eight areas for you to examine with a telescope that tell the story of the past, present and future of our nearest neighbour. Let's start by rolling the clock back to the Moon's early days.

1. The seas of the lunar nearside

Eons of heavy bombardment formed the Moon's basins

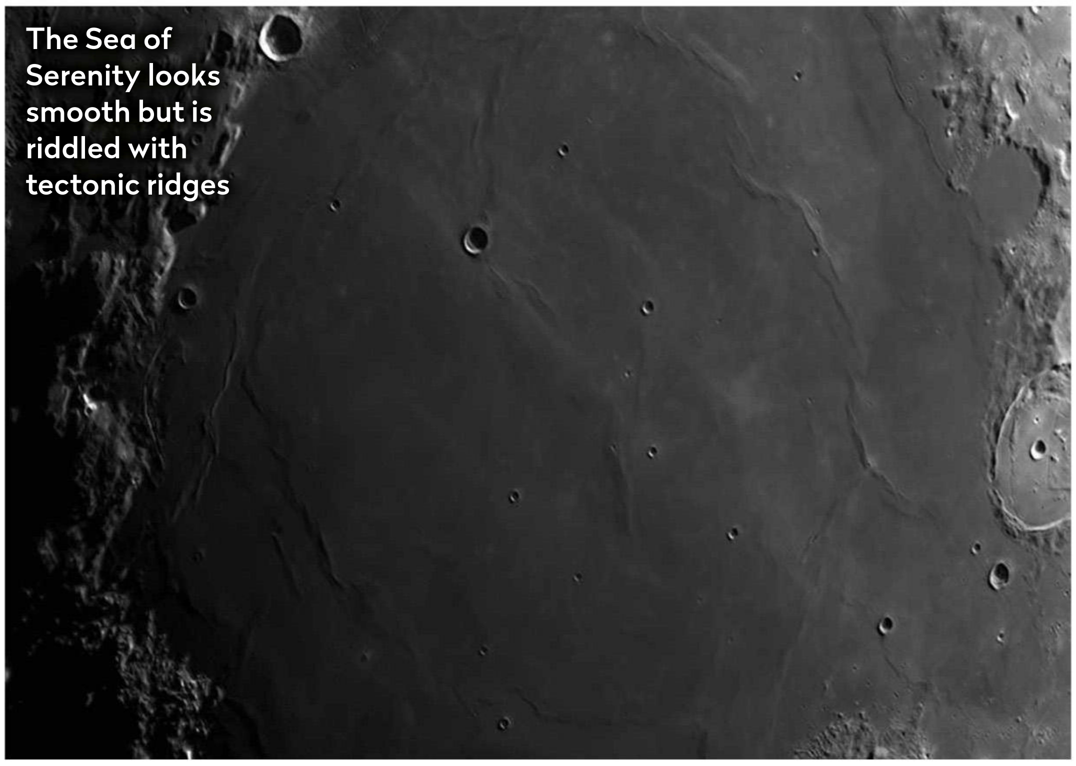
About 4.5 billion years ago, the Moon was formed in a violent impact when an object about the size of Mars smashed into the early Earth. This cataclysm left a cloud of superheated material circling Earth that, so our current understanding goes, eventually coalesced into the Moon. After around 500 million years, our companion in space had cooled to form a solid body, rather than a seething ball of molten rock. But it was around this time that another series of massive impacts are thought to have occurred. These punched into the lunar globe, leaving enormous scars across its surface, known as basins.

Over time these are believed to have been filled in by immense flows of molten rock from within the Moon, becoming the lunar 'seas' we observe on the Moon today. Known to astronomers as 'maria', these dark regions create the 'face' in the Moon and are visible to even the naked eye. They are made of dark, basaltic rock and extend in vast, vaguely circular plains across much of the lunar nearside. One of the most interesting to observe with a small telescope is the Mare Nectaris, in the southeast quadrant of the Moon's disc. Thought to be just under four billion years old, when the lighting conditions are right – as they will be on the nights of 12 and 29 November – you can still see hints of concentric ring shapes thought to be left over from its formation.

Mare Nectaris, an easy spot with its bright stripe, is an impact basin that flooded with lava

2. Mare Serenitatis wrinkle ridges

A shrinking skin lined the Moon's face with wrinkles



The Sea of Serenity looks smooth but is riddled with tectonic ridges

As you cast your eye over some of the lunar seas at the telescope eyepiece, you may notice that these ostensibly smooth basalt plains actually show subtle textures. Not only are there clear variations in their colour – or rather shade of grey – but they also contain features where the land rises and falls in distinct narrow ridges, winding across the surface. These are known as 'wrinkle ridges' and for a while there was a debate about how exactly they formed. Were they volcanic in origin or a product of the seas deforming as these landscapes contracted after their formation? Scientists now think that in most cases it was likely the latter: the ridges emerged when the lunar seas experienced underground movements that wrinkled up the expansive basalt plains above.

With a small telescope of around 4–6 inches in aperture, the best time to look for wrinkle ridges is when they are illuminated obliquely, that is when they are positioned near to the terminator. We've chosen to highlight Mare Serenitatis, pretty much the entirety of which is criss-crossed by wrinkle ridges, and which recent research suggests formed around 3.4 billion years ago. They will be well-lit on 12 and 13 November. There are also some other wonderful examples in the northern Mare Imbrium, close to the Bay of Rainbows, so you may want to note when the terminator passes through the region. ▸

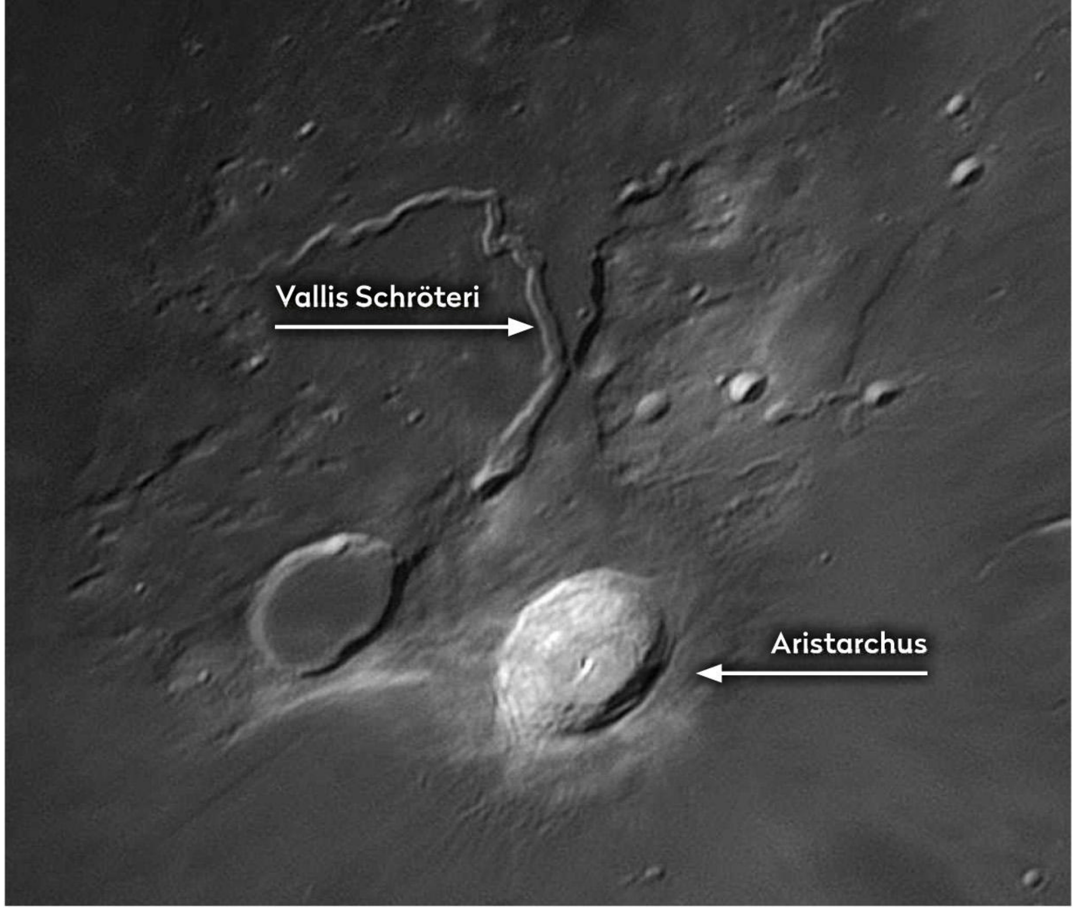
ALL PICTURES: WILL GATER

3. Vallis Schröteri

An immense eruption made the longest valley on the Moon's near side

Lunar volcanism has sculpted and shaped many of the surface features we see through a telescope today. The next two stop-offs in our history of the Moon demonstrate this perfectly.

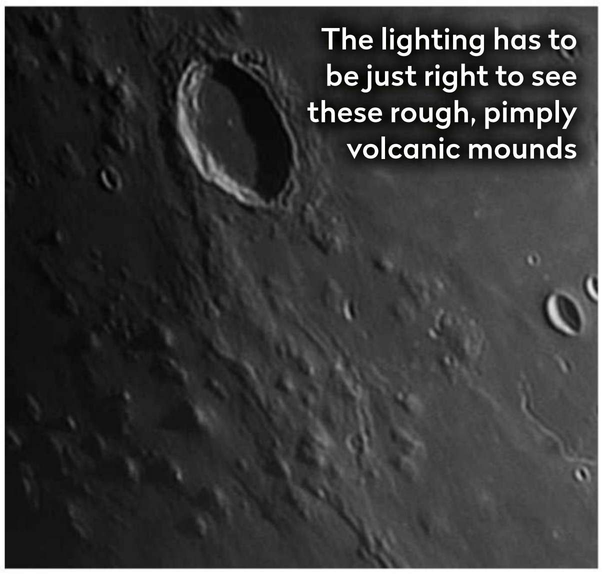
Within the great expanse of the lunar sea known as Oceanus Procellarum, on the western side of the Moon, lies the striking crater Aristarchus. You can't miss it. Even in binoculars its bright walls stand out prominently from the darker plains surrounding it. Yet, look at it with a telescope and you'll notice there's an even more intriguing feature than Aristarchus lying close by. Extending away from the crater to the northwest is a wiggling line, known as the Vallis Schröteri or Schröter's Valley. This is what lunar geologists refer to as a 'sinuous rille' and it is thought to have been formed about 2.5 billion years ago when an immense eruption of lava carved a long, valley-like path through the landscape. In total Vallis Schröteri wanders over 160km across the lunar surface and is around 500 metres deep. Its large extent means that the valley is pretty easy to see in a small scope – though as we've seen with other features, the right illumination is key. To really see it well this month, aim to observe it on the nights of 6 and 7 November, as well as 18 November.



▲ **The snake-like 160km valley sits close to prominent crater Aristarchus, terminating in a wide feature called the Cobra's Head**

4. The Marius Hills

A landscape littered with enigmatic volcanic lunar domes



The lighting has to be just right to see these rough, pimply volcanic mounds

Heading south across the Oceanus Procellarum we reach another volcanic landscape thought to have emerged two to three billion years ago, but which may be as young as 800 million years in places. The surface here, west of the bright crater Kepler, is dominated by huge areas of flat lunar sea and a scattering of moderately-sized craters. Yet when the terminator sits close to the crater Marius, it is possible to see that there are numerous small peaks in this region rising up from the smooth basalt surroundings of Procellarum.

These raised 'bumps' are known as the Marius Hills. Referred to as lunar domes, they are similar to shield volcanoes on Earth, which form when lava oozes onto the surface creating rounded volcanic peaks. Magma coming up from deep below the surface may then have caused further eruptions that formed the valley-like rilles in this area. These can also be photographed with modest imaging equipment on large telescopes. To see the Marius Hills well visually, though, you'll need a telescope of 150–200mm and a night of good seeing.

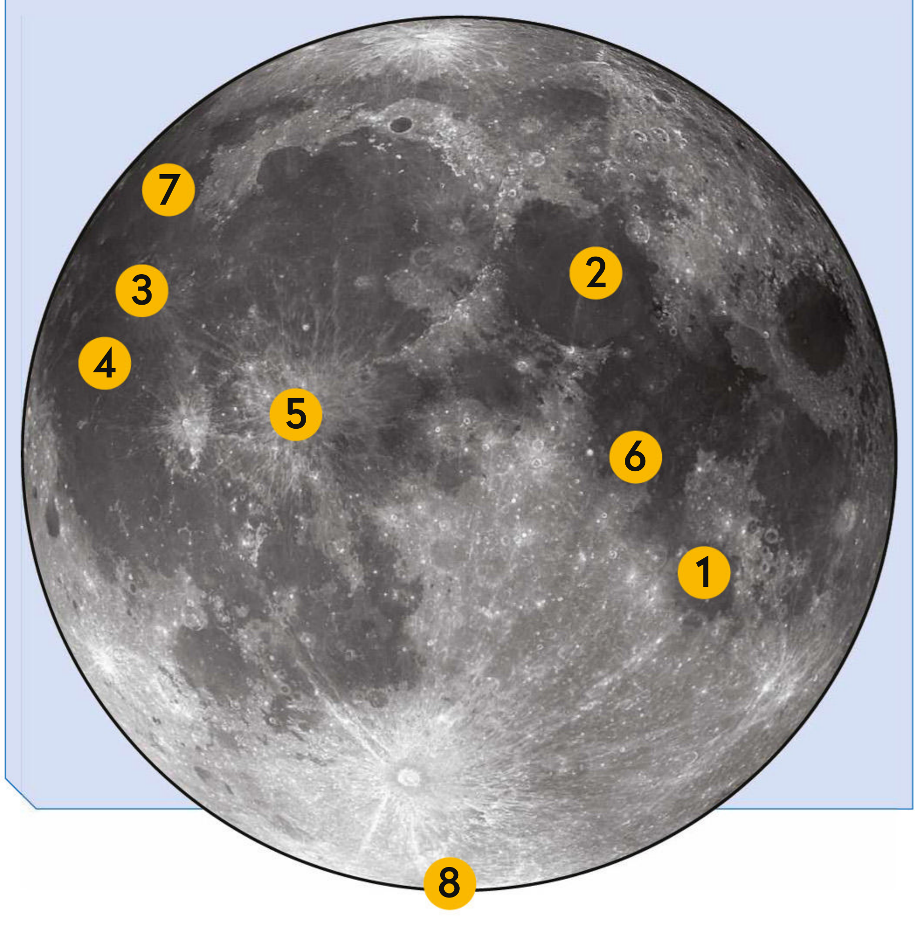
WILL GATER X 4, PETE LAWRENCE, NASA GODDARD/ARIZONA STATE UNIVERSITY

What kit to use

Naked eye | Binoculars | Small telescope | Large telescope

Where to find our eight lunar features

An at-a-glance observing guide

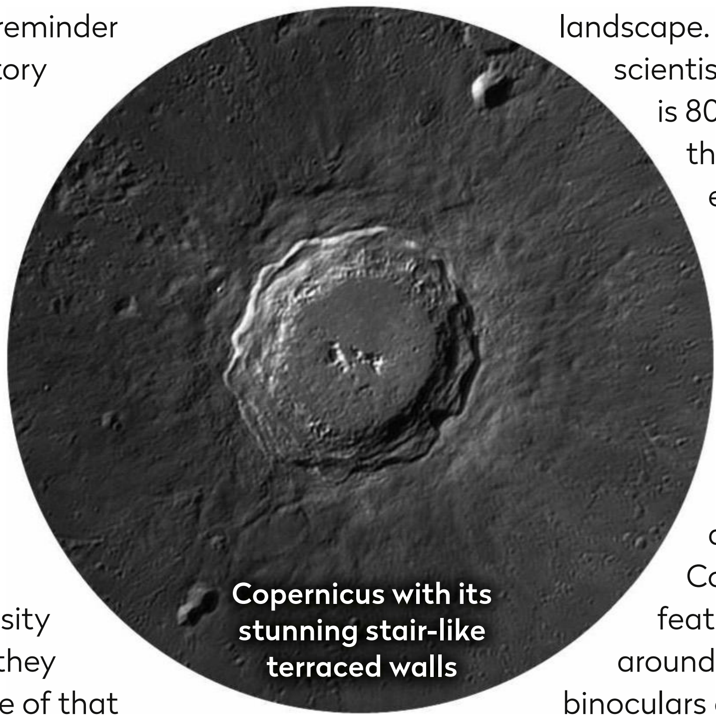


5. Copernicus crater

Apollo 12 and 14 explored south of the crater and returned samples of ejecta from its formation

There is perhaps no better reminder of the Moon's dramatic history than the myriad craters that pepper its globe – from the centimetre-sized ones visible in Apollo surface images, all the way up to those large enough to see from Earth with the naked eye. The rate of asteroid and comet impacts has dropped off over time, but even today small meteoroids still slam into the surface.

The craters of the Moon have been central to piecing together its history. When linked to the samples returned home by the US Apollo missions, the density of craters on any given surface and how they overlap can be used as proxies for the age of that landscape. Detective work like this leads planetary scientists to believe that the crater Copernicus is 800 million years old. Its formation marks the start of the 'Copernican' era that extends to the present.



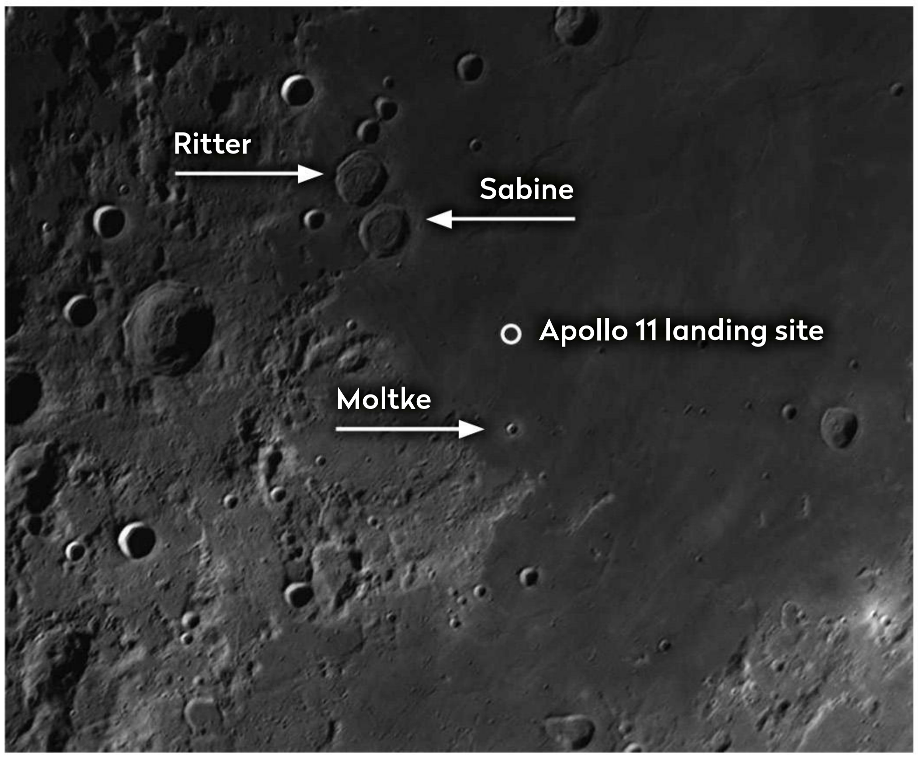
Copernicus with its stunning stair-like terraced walls

Copernicus is one of the Moon's most visually stunning craters. As well as having rippling terraced walls that change appearance over the lunar day, it is surrounded by an impressive ray system. These were made when ejecta was thrown over 600km away during the violent impact that created Copernicus. To see this extraordinary feature for yourself, seek it out on the nights around 4 November and 15 November using binoculars or a small telescope.

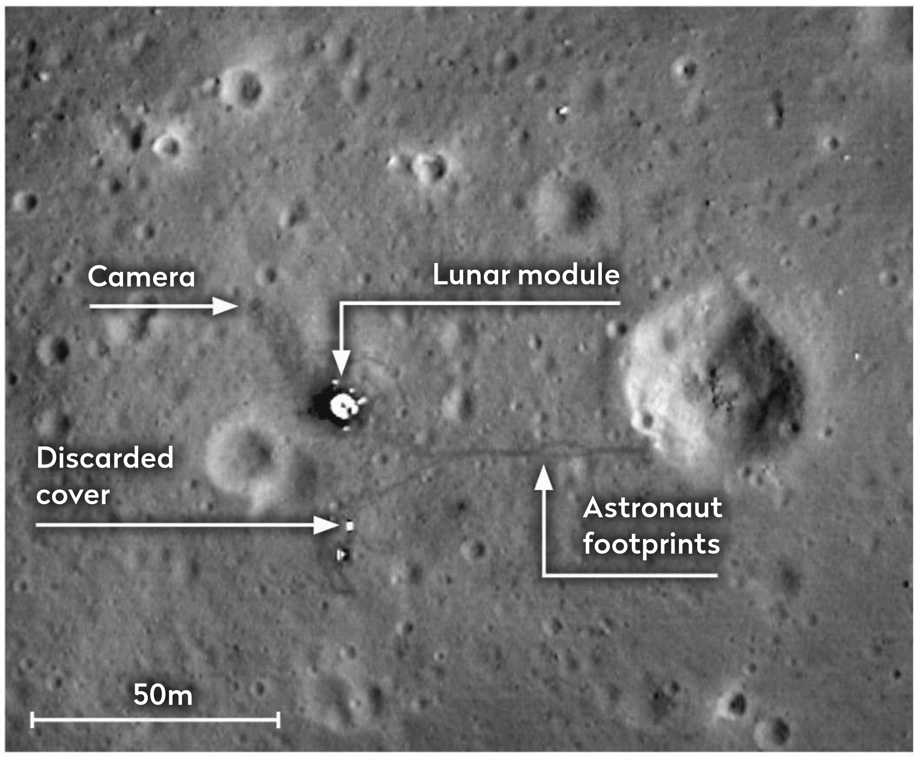
6. The Apollo 11 landing site

A small moment in the Moon's lifetime, but a giant leap for mankind

Our next stop brings us to where the timeline of our own species and that of our nearest neighbour intersect. More than 50 years ago, humanity made its first steps onto another world during the Apollo 11 mission. The landing site where US astronauts Neil Armstrong and Edwin 'Buzz' Aldrin completed that historic exploration lies in the southern half of the Mare Tranquillitatis, the Sea of Tranquility. While it is not possible to see any of the mission hardware that the crew left there with a telescope from Earth, NASA's Lunar Reconnaissance Orbiter in orbit around the Moon has been able to photograph the lunar module descent stage and trails left by the astronauts. It can still be fun to track down the landing area at the eyepiece, though. This month, 11 and 12 November are good nights to go looking for it. First locate the pair of craters Ritter and Sabine on the edge of the Mare Tranquillitatis. Then track your eye towards the promontory that pokes out into the sea close to the crater Moltke. About half way along this line is the area where Apollo 11 landed. ▸



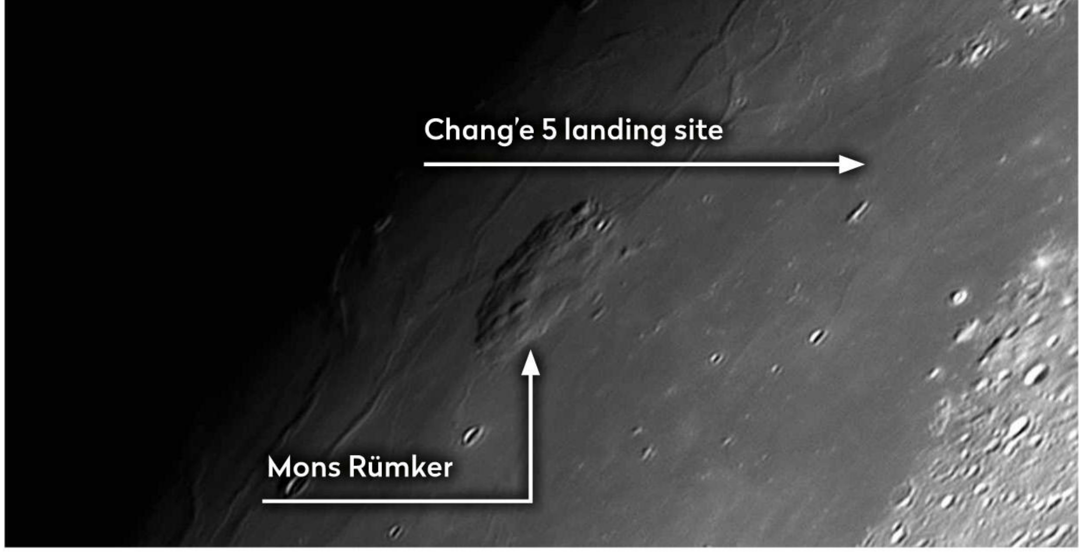
▲ **In the southern Sea of Tranquility, track down from crater duo Ritter and Sabine towards Moltke to find Apollo 11's landing site**



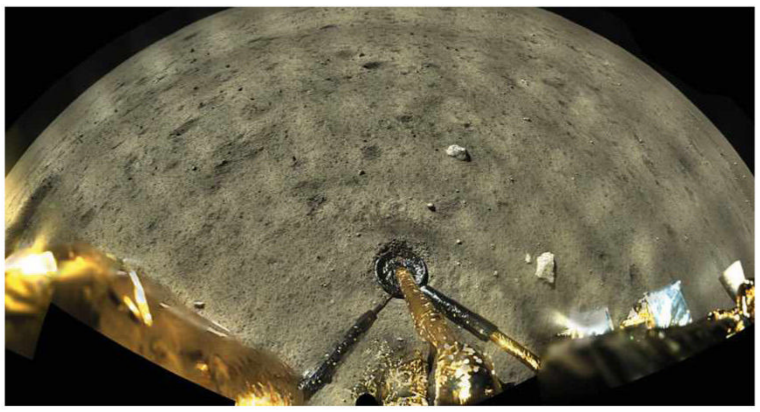
▲ **A Lunar Reconnaissance Orbiter photo taken from just 24km up shows the tracks from Aldrin and Armstrong's 2.5-hour moonwalk**

7. Chang'e 5 landing region

The vast Ocean of Storms, where the Chinese led the vanguard of modern missions



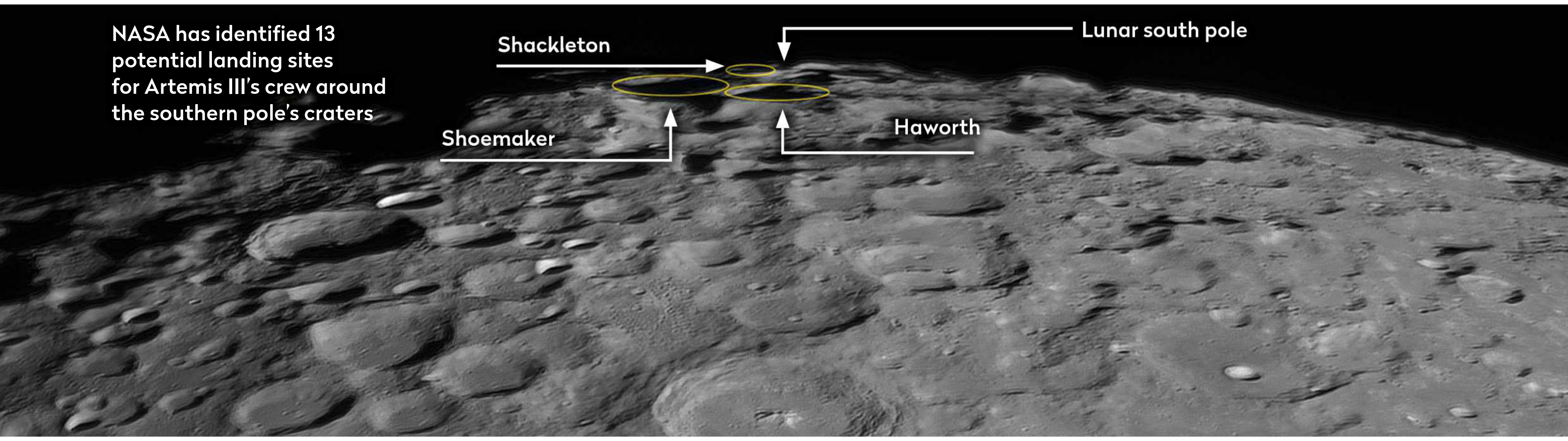
▲ The solidified magma surface of Oceanus Procellarum where Chang'e 5 landed



► The spacecraft drilled and scooped rock and soil from the region in late 2020

We may not have walked on the Moon for decades, but uncrewed missions have continued to explore it in our place. Today, the US Lunar Reconnaissance Orbiter circles the Moon capturing exquisitely detailed images, while recent Chinese missions have heralded a new era of robotic lunar surface exploration.

Among these is the Chang'e 3 mission, whose lander and rover touched down in 2013, and the Chang'e 4 mission that made the first landing on the lunar far side, in Von Kármán crater, in 2019. It was able to return high-resolution images of the area and deploy a rover to explore features up-close. Another success for the Chinese came in 2020, with the landing of Chang'e 5. It was deployed to a landing site in the northern Oceanus Procellarum or Ocean of Storms, where it gathered almost 2kg of samples that were returned to Earth by a spacecraft waiting in lunar orbit. Chang'e 4's landing site is hidden from view on the far side, but with a small telescope it is possible to see the wide region that Chang'e 5 studied. The landing site is a little way northeast of the fascinating volcanic feature Mons Rümker, which will be well-positioned for observation on 7, 8 and 9 November.



NASA has identified 13 potential landing sites for Artemis III's crew around the southern pole's craters

8. The lunar south pole

The first woman on the Moon will probably walk at its southern pole

We finish our observing tour with a look to the future. While the Moon will be largely unchanged for eons, it may once again become a destination that humans visit and explore. Certainly that's the hope of many space agencies and commercial entities around the world.

But such plans have been mooted for decades and deadlines all too often slip further beyond the horizon. Will the current push to return there, perhaps for longer periods, be the one that finally happens? If it is, there is one place that will be high on the list of possible landing sites: the lunar south pole region, near Shackleton crater. In fact, NASA has already picked out several potential landing spots in the region for its planned human landing mission, Artemis III. There, permanently shadowed craters offer the promise of water-ice, which could be used for making rocket fuel, while sunlit peaks and crater rims provide sites for bases with solar panels. For us amateur astronomers, the south pole region is also a fascinating area to take in at the eyepiece, with huge craters, mountains and undulating terrain creating a rich and captivating view in medium- to large-aperture telescopes using high magnification. Cast your eye over it when conditions are favourable on the nights of 11 and 12 November, because it could be a place where the next chapter in the Moon's history is about to be written...

Will Gater is an astronomy journalist, author and presenter

WILL GATER X 2, CNSA/CLEP

Scanning the dark Universe with the

VERA RUBIN OBSERVATORY

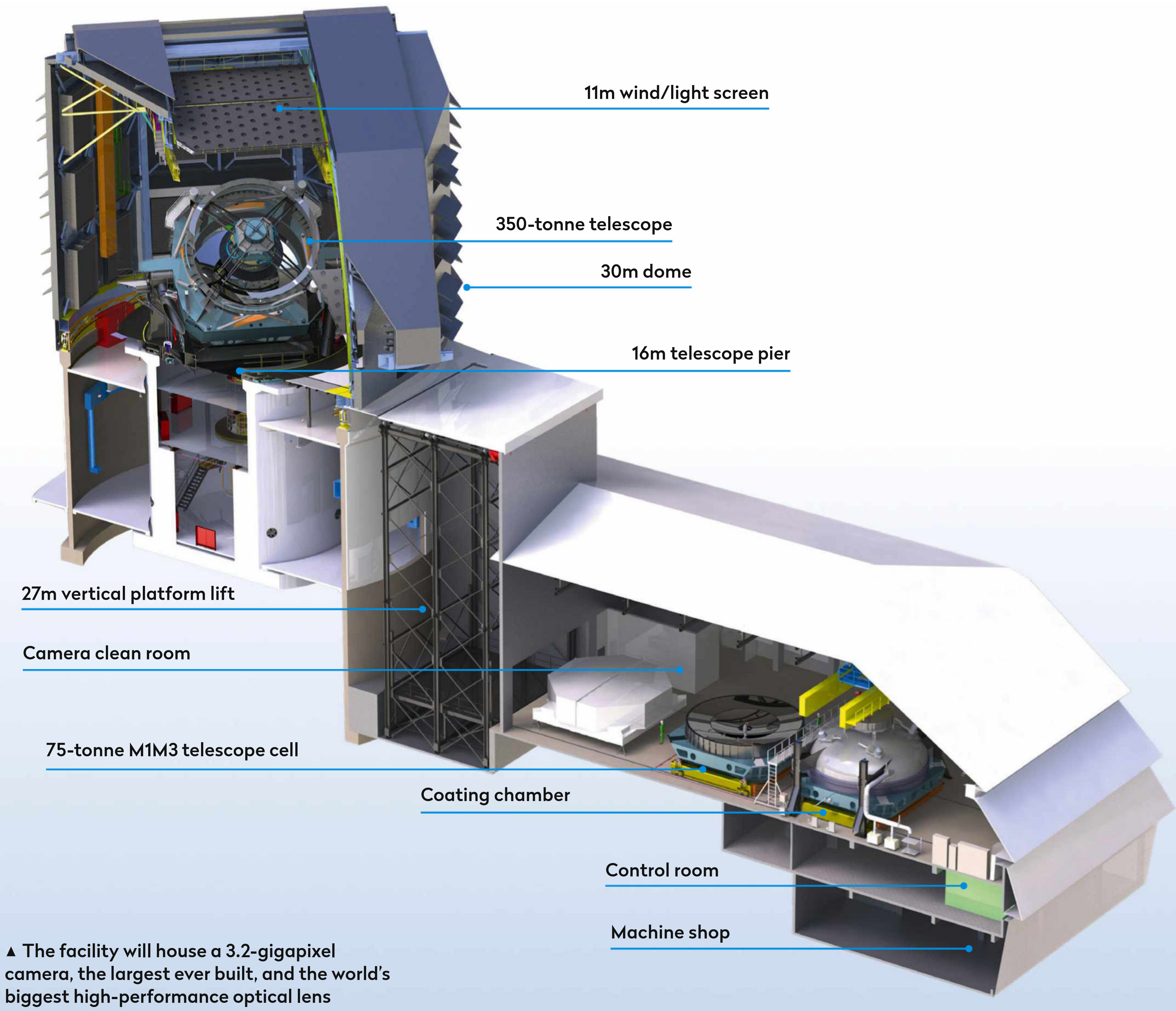
Govert Schilling visits the revolutionary new observatory in Chile that's set to lift the lid on the mysterious, invisible dark matter that dominates the Universe

RUBIN OBSERVATORY/NOIRLAB/AURA/NSF/B. QUINT

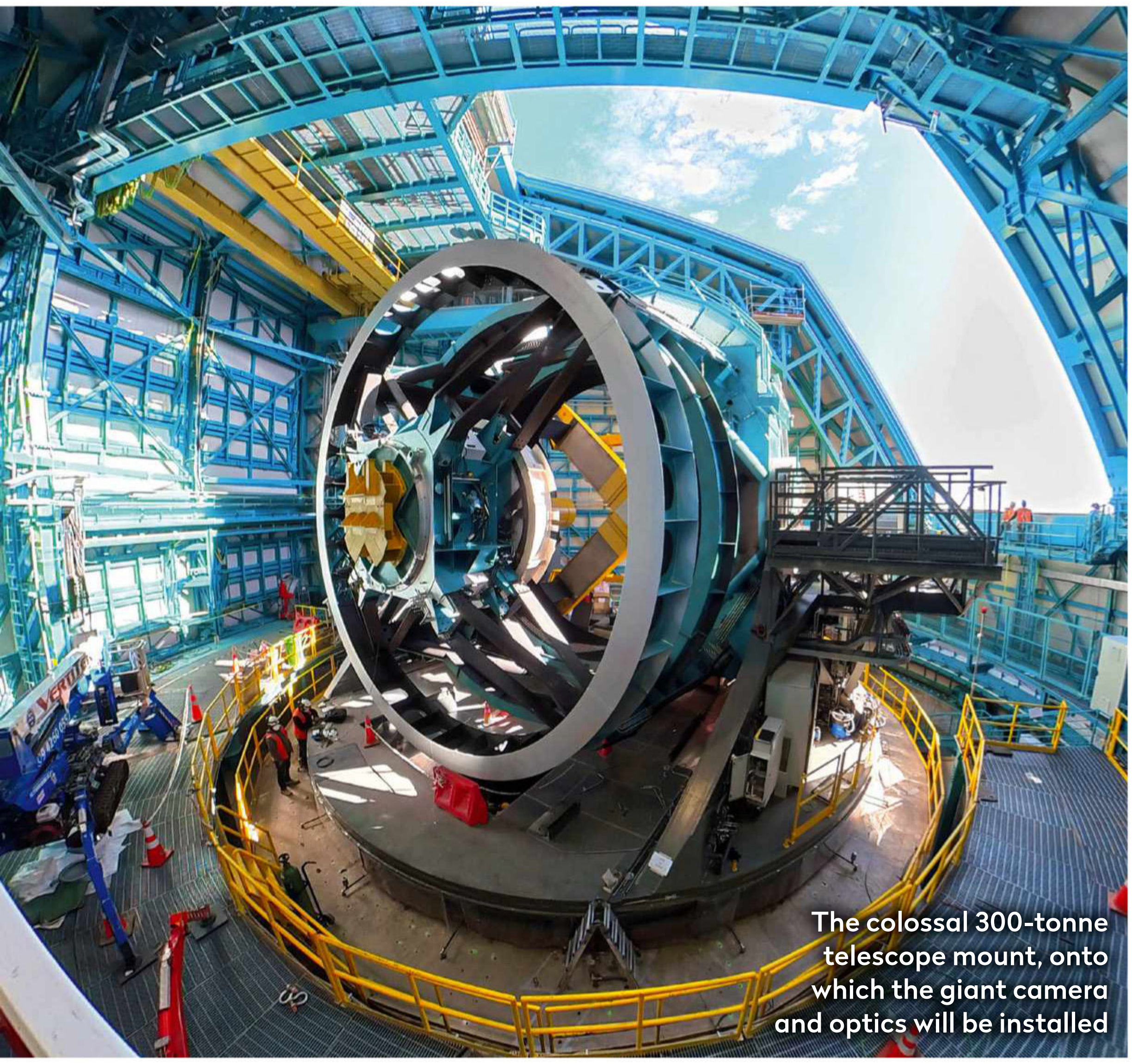
Some 15 minutes west of the town of Vicuña, in the Valle del Elqui in northern Chile, a steep and winding gravel road leads south from Highway 41 to the summit of Cerro Pachón, almost 2,700 metres above sea level. Since the early 2000s, the mountaintop has been home to the 8.1-metre Gemini South Telescope and the 4.1-metre Southern Astrophysical Research Telescope. But today, the scene is dominated by a huge, futuristic cylindrical building, housing a revolutionary telescope that will uncover the Universe's darkest secrets. Welcome to the Vera C Rubin Observatory.

The observatory's main telescope is unlike any other ever built. Its 8.4-metre diameter mirror – a novel combination of a ring-like primary mirror surrounding a much more strongly curved tertiary mirror cut from the same glass blank – has a giant 3.5° field of view, as wide as seven full Moons strung together. Two to three times a week, a monstrous 3.2-gigapixel digital camera – the largest ever built – will snap a razor-sharp and extremely deep image every 30 seconds, covering all of the night sky visible from Chile. In 10 years' time, each and every visible star and galaxy in the southern sky will have been visited by Rubin at least 800 times: the most comprehensive survey of the cosmos ever made. ▸

High and mighty: Rubin Observatory will produce the deepest ever image of the entire southern sky



▲ **The facility will house a 3.2-gigapixel camera, the largest ever built, and the world's biggest high-performance optical lens**



The colossal 300-tonne telescope mount, onto which the giant camera and optics will be installed

▸ "Rubin is absolutely unique," says Robert Blum, director for operations of the observatory. "Nothing like this survey has been done before."

Cosmologist Catherine Heymans of the Royal Observatory Edinburgh, and the Astronomer Royal for Scotland, is equally thrilled. "This visionary project has been part of my academic life since I started my PhD in 2000," she says. "I was so delighted when the UK joined Rubin in 2015 and I officially became a part of this groundbreaking new initiative. Everyone is excited about what we might find."

Completion of the new observatory, which is a partnership of the US National Science Foundation (NSF) and the US Department of Energy (DOE), was delayed by a couple of years because of the COVID-19 pandemic, but according to Blum, first light is now expected in early 2024, with full science operations scheduled to start later that year. "All of the main telescope subsystems and mirrors are in Chile and nearly ready for integration," he says. Initial alignment of the system, including installation of a smaller commissioning camera, should have been done by the time you read this article. "We hope to ship the main camera to Chile around February 2023," says Blum.

This giant camera, built by DOE's SLAC National Accelerator Laboratory in California and weighing

Rubin's goals include unravelling how dark energy influences galaxy clusters like the Virgo Cluster

more than three tonnes, is an engineering marvel in itself. Its 25-inch diameter focal plane is covered by 189 CCD detectors of 16 million pixels each. Cooled down to –100°C for better sensitivity, the array registers stars as faint as 25th magnitude in exposures of a mere 30 seconds through one of six broadband filters. After each exposure, the extremely compact and stiff telescope will slew to its next position in just five seconds, night after cloudless night. Known as the Legacy Survey of Space and Time (LSST), the project will take a whopping 200,000 images per year and has an expected data rate of 10–20 terabytes every night.

Bigger, wider, deeper

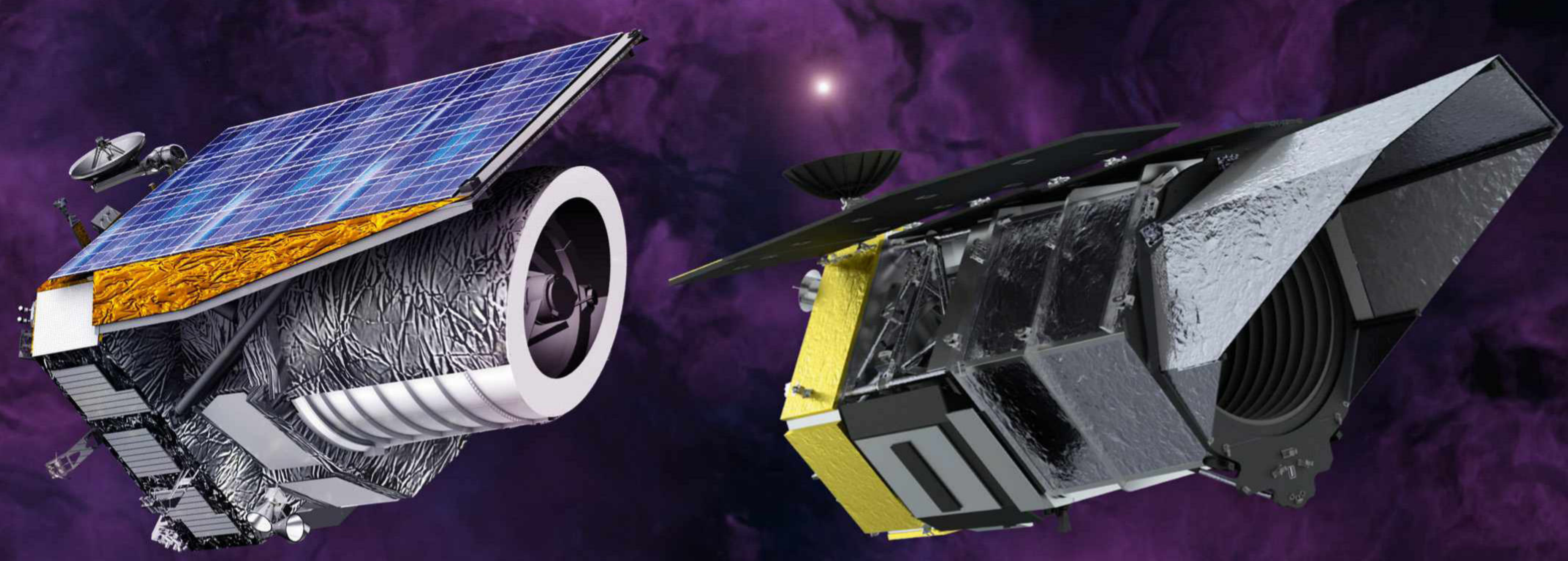
LSST is not the first deep cosmological survey. "There have been some wonderful projects before," says camera project scientist Steven Ritz from University of California at Santa Cruz, "but the combination of the Vera C Rubin Observatory's large field of view and depth really makes for something new altogether."

Heymans notes that Rubin will cover almost 700 times the area of the Hyper Suprime-Cam (HSC) deep survey on the Japanese 8.2-metre Subaru Telescope in Hawaii (which has a more or less comparable sensitivity), while it produces significantly deeper images than the Dark Energy Survey (DES) on the nearby 4-metre Victor M Blanco Telescope at Cerro Tololo Inter-American Observatory, which covered 3.6 times less sky than Rubin will.

Like DES and the smaller HSC survey, the Legacy Survey of Space and Time is a dark energy experiment. Dark energy is a theoretical energy that is pushing the Universe apart, which has been hypothesised to explain why cosmic expansion is accelerating. One of the goals of the Rubin Observatory is to find out how this mysterious property has evolved over cosmic time and how it has influenced the growth of large-scale structures like clusters and superclusters. This can be achieved by precisely mapping the three-dimensional distribution of billions of galaxies.

▲ **The camera team celebrate attaching the cryostat, with its 28-inch lens and 201 sensors, onto the camera body**

Moreover, it will be able to study minute distortions in the images of galaxies – caused by a phenomenon known as weak gravitational lensing – which can directly measure how mass is distributed in space, ▸



▲ Like Rubin, Euclid (left) and Nancy Roman (right) will scour the skies for dark energy and dark matter

The view from space

Two upcoming space telescopes will work together with Rubin to understand the unseen Universe

In 2023, even before the Vera C Rubin Observatory begins its unprecedentedly thorough survey of the distant Universe, the European Space Agency will launch its 1.2-metre diameter Euclid space telescope, which is pursuing very similar goals: studying dark energy and dark matter by precisely mapping and imaging billions of galaxies. Four years later, NASA will follow suit with its 2.4-metre Nancy Grace Roman Space Telescope. So how do the three projects compare?

According to Catherine Heymans from the Royal Observatory Edinburgh, Rubin will dwarf Euclid and Roman in terms of sensitivity, because of its much larger primary mirror. But, she adds, the Rubin Observatory sits underneath the Earth's atmosphere and won't be able to obtain images as crisp as those captured by the two space telescopes.

"The secret that is rarely openly discussed, however," she says, "is that these telescopes need each other in order to truly succeed in their scientific goals. Euclid requires Rubin's multicolour imaging, and Rubin can benefit from high-resolution data [from space] to untangle the many blended galaxy images it will see."

How exactly the data from these instruments will be combined is still a topic of hot discussion, says Heymans, but by working together they will be able to address a wide array of different science goals.

ILLUSTRATION

▸ including the invisible dark matter that is believed to make up some 85 per cent of all the gravitating stuff in the Universe.

Astronomers are confident that dark energy and dark matter play a pivotal role in the evolution of the Universe, but they have few clues as to the true nature of these two mysterious ingredients. "With the avalanche of data that Rubin brings, we will be confronting a wide range of both conventional and exotic theories on the dark side of our Universe," says Heymans.

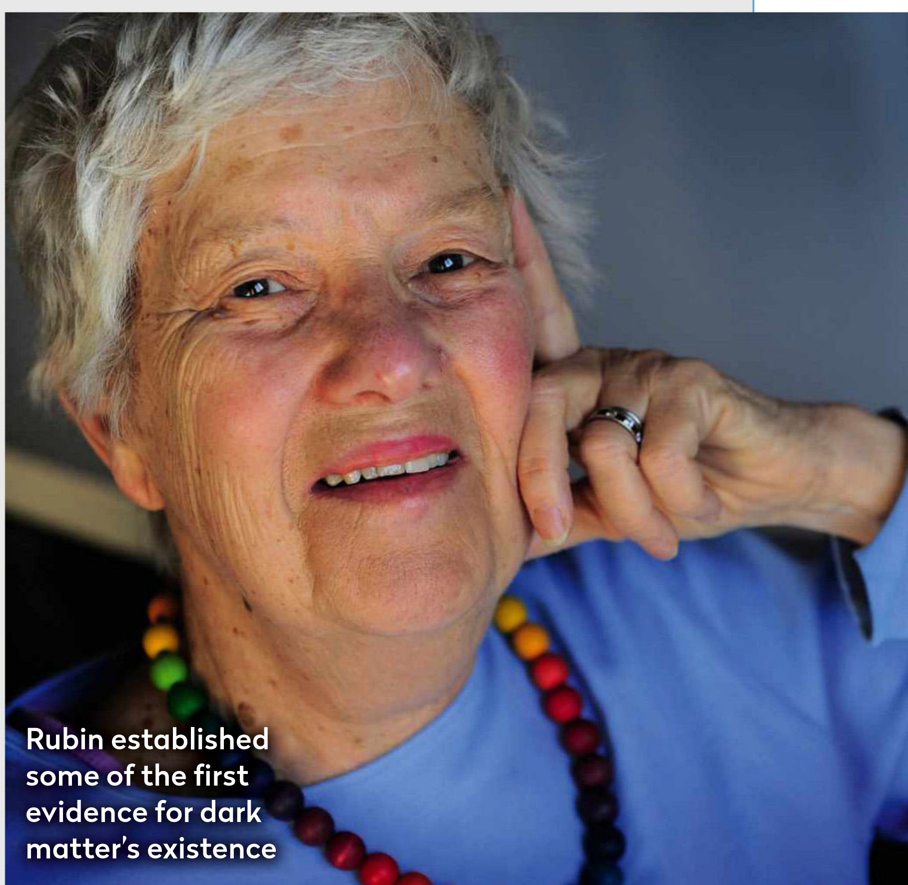
Apart from stationary stars and galaxies, Rubin will also discover millions of moving objects, like remote comets, asteroids, Kuiper Belt objects (which lie beyond Neptune's orbit), near-Earth objects that might pose an impact threat to our home planet,

The name game

The observatory is named after pioneering astronomer Vera C Rubin

The revolutionary telescope under construction at Cerro Pachón was originally called the Large Synoptic Survey Telescope, but in early 2020 it was announced the new observatory would be named after American astronomer Vera C Rubin (1928–2016). Starting in the late 1960s, Rubin, together with her Carnegie Institution of Washington colleague Kent Ford, measured the rotational properties of the Andromeda Galaxy and a number of other nearby spiral galaxies, and found convincing evidence for the existence of invisible, dark matter in the outskirts of these stellar systems.

The concept of dark matter is much older and radio astronomers had made similar observations before, but US Congress decided on the name change to honour Rubin's pioneering work in the field of dark matter research, as well as in overcoming gender-based discrimination, paving the way for other women in astronomy. The 8.4-metre telescope of the observatory is now officially known as the Simonyi Survey Telescope, after a major private donor. Meanwhile, the original acronym LSST was saved: it now denotes the observatory's Legacy Survey of Space and Time.



Rubin established some of the first evidence for dark matter's existence

FABIAN NEYER/CCDGUIDECOM, GETTY, NAZARII NESHCHERENSKYI/ISTOCK/GETTY IMAGES

Interview: J Anthony Tyson

Tyson first proposed the observatory that would become Rubin in 1996, directed the project for 15 years and is now its chief scientist

What are the differences between your original Dark Matter Telescope proposal and the final observatory?
Not that much. The large aperture and the corresponding need for a gigapixel camera are set by the needed throughput to carry out one comprehensive deep-sky survey. So that hasn't changed. The main difference is the huge effort we have put into data management and software development.

How has the 1998 discovery of dark energy impacted the science case for the project?
The discovery of dark energy, using a previous camera we built called the Big Throughput Camera, added an important new science motivation for what was originally called the Large Synoptic Survey Telescope [now renamed the Legacy Survey of Space and Time]. But an even more important development has been the growth of time-domain astronomy. A good example is gravitational wave bursts, which Rubin will follow up.

Which results are you looking forward to most?
My main interest is in cosmology; the 'new' physics of dark matter and dark energy. There are multiple probes of that with the upcoming survey. But I'm most excited about the discovery of the unexpected.

Planet Nine – an unseen ninth world possibly hiding in our Solar System – could finally be within grasp

ILLUSTRATION

and maybe even the hypothetical Planet Nine in the distant reaches of the Solar System. "The wealth of new Solar System objects we will uncover is super-exciting," says Blum.

There are many other discovery opportunities, especially in time-domain astronomy: the ability to study how the whole sky changes over a wide range of timescales, which Heymans refers to as 'whoosh-flash-bang astronomy'.

"There's a lot going on that we don't yet understand," says Ritz.

Data avalanche on its way

Rubin's repeated visits to the same areas of sky will yield hundreds of 'alerts' per second where something has changed: countless variable stars, stellar flares, novae and supernovae, but also the optical counterparts of explosive events like gamma-ray bursts, fast radio bursts, tidal disruption events and gravitational wave sources.

"I am most excited to see how our community works with the alert stream," says Blum. "I am also anxious to see how successful we will be in setting up a network of telescopes for follow-up observations."

Operated by NSF's National Optical-Infrared Astronomy Research Laboratory (NOIRLab) and SLAC, the Vera C Rubin Observatory will take 10 years to complete the LSST project. Right now, no one knows what it will bring.

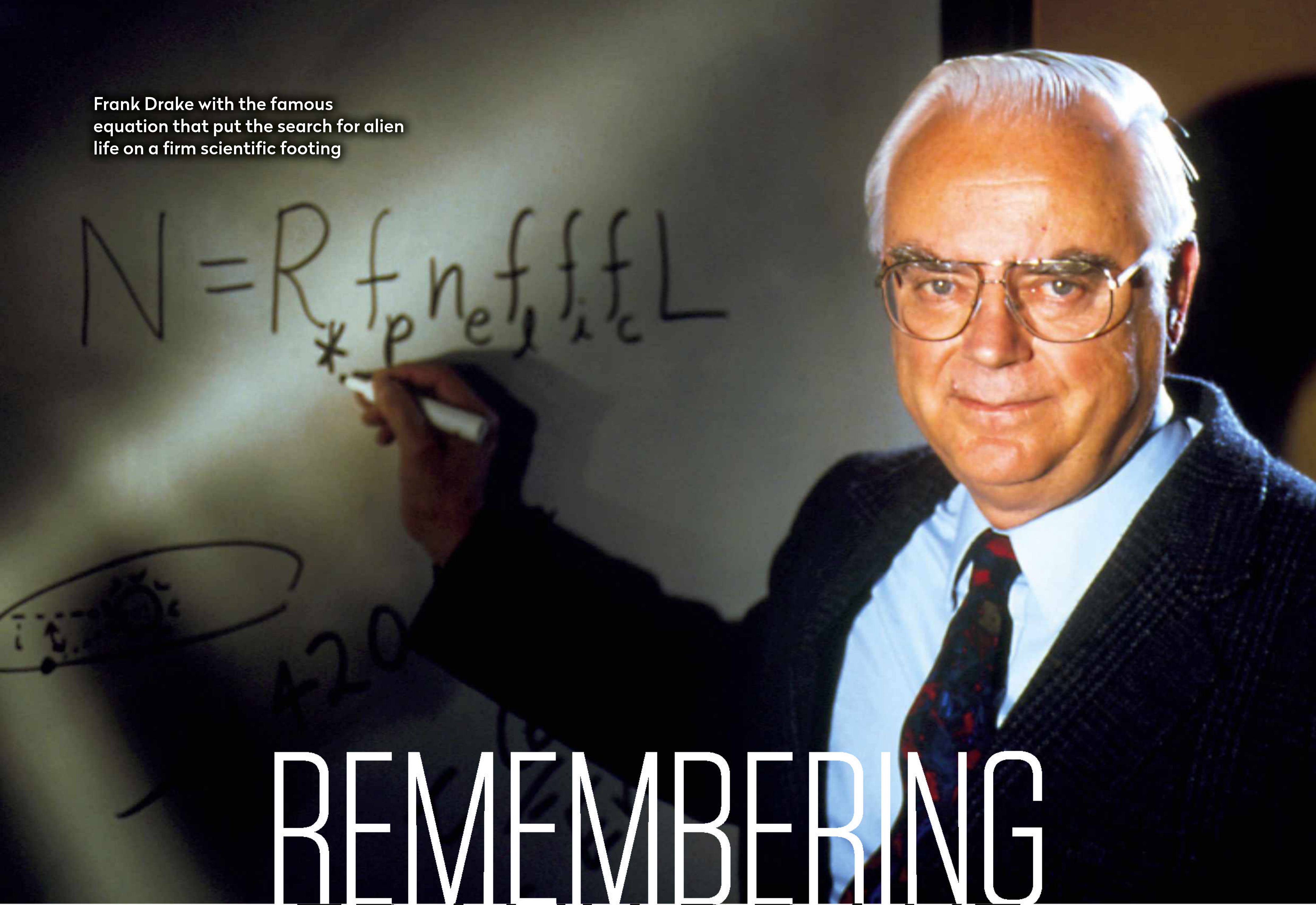
"I have learned not to speculate," says Ritz. "Science often has surprises, which is great. We really want to see what doesn't fit our expectations, because that's often the first step in a great discovery."

As for the cosmological conundrums that scientists are faced with, Heymans sees two possible scenarios. The first is what many astronomers already think is the case: that dark energy doesn't change over time. "I fear that would lead us no further in our journey to truly understand the origin of the dark Universe," says Blum.

"The second scenario is that we find evidence of dark energy evolving and changing with time or space. That would allow for the existence of a new force field, which could possibly be coupled to the gravitational field.

Who knows what we'll find – but with Rubin the discovery potential is endless."

Govert Schilling's book *The Elephant in the Universe* is published by Harvard University Press



Frank Drake with the famous equation that put the search for alien life on a firm scientific footing

REMEMBERING FRANK DRAKE

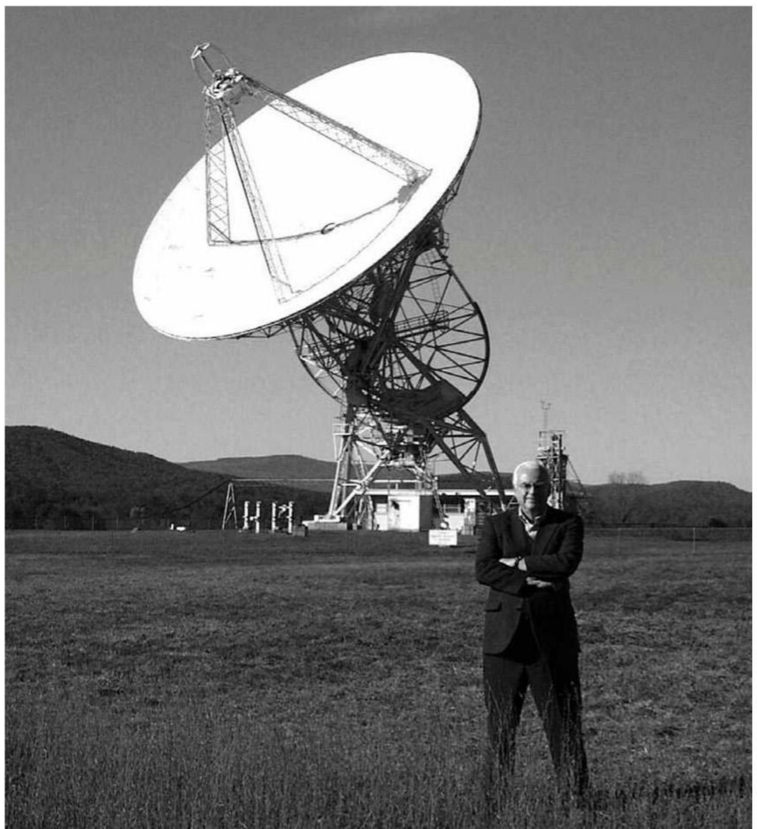
Drake's work transformed the hunt for alien civilisations from a fringe interest into a legitimate field of scientific inquiry

One of the foremost pioneers in the search for extraterrestrial life (SETI), Frank Drake, died on 2 September 2022 at the age of 92.

Born on 28 May 1930 in Chicago, Drake first began wondering about extraterrestrial civilisations at the age of eight, when his father told him of the existence of worlds beyond Earth. At 17, he enrolled at Cornell University on a Navy scholarship, initially intending to be an airplane designer, but he changed his plans when he first glimpsed the moons of Jupiter during an astronomy lesson. This renewed his curiosity about whether alien life existed and, crucially, how it could be discovered.

Drake began his PhD at Harvard University in 1952, studying star formation and investigating the planets of the Solar System by bouncing radio waves off them. It was here he first theorised that extraterrestrial life may also be emitting radio signals that could be detectable.

After serving in the Navy from 1955 to 1958, Drake took a position at the National Radio Astronomy Observatory at Green Bank, West Virginia, in April 1958. He used the 26-metre radio telescope to pierce through the cosmic dust and map the centre of the Milky Way for the first time. He also discovered the radiation belts around Jupiter and measured the scorching temperature of Venus's surface.



◄ As a staff astronomer at Green Bank's Tatel Telescope, Drake embarked on a search for radio signals coming from the heart of our Galaxy

DR SETH SHOSTAK/SCIENCE PHOTO LIBRARY, NRAO/AUI/NSF X 2, NASA/JPL X 2

The Drake equation

Drake's eponymous 1961 equation is a formula for assessing the likelihood of advanced civilisations in the Milky Way, and has shaped SETI ever since

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Number of detectable extraterrestrial civilisations in the Milky Way (N)

Rate at which stars in the Milky Way are born Current estimates put this at between five and 20 stars per year. (R_*)

Fraction of stars with planets A complete unknown when the equation was written; exoplanet research in the last 30 years suggests most stars have planetary systems. (f_p)

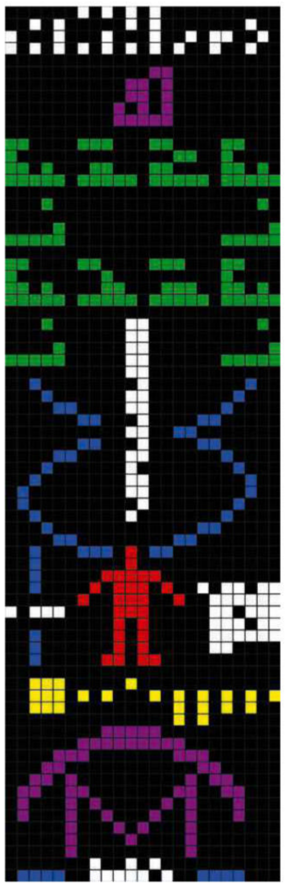
Number of habitable planets per system 'Habitable' is usually defined as a planet where the temperature is right for liquid oceans to form, but in reality hundreds of factors affect suitability for life. (n_e)

Fraction of planets on which life appears Some biologists say that if conditions are right life will emerge, but this is highly contested. (f_l)

Fraction of those planets that develop intelligent life Another controversial value. The billions of species on Earth show life does become more complex over time, suggesting intelligence could be inevitable. (f_i)

Fraction sending signals into space This is almost impossible to predict. Would a distant civilisation even want to reach out to its neighbours? (f_c)

Length of time such civilisations send detectable signals In cosmic timescales, could the signals still be transmitting? In our billion-year history, we have only been sending radio signals for 100 years. (L)



▲ **The message to the globular cluster M13, transmitted from the Arecibo Radio Telescope in 1974**

But the telescope at Green Bank was also powerful enough to detect radio signals (extraterrestrial or not) from up to 12 lightyears away – a volume encompassing around 30 stars. On 8 April 1960, Drake and several colleagues embarked on Project Ozma, searching for signs of life around two specific Sun-like stars. They did so in secret, scared of public ridicule, and after two months found nothing. Despite this, Drake published the study. It would turn out to be a career-making decision. Firstly, it inspired astronomer Carl Sagan to reach out to him, and secondly, his work led to him being asked to organise the first-ever conference on the search for life on other planets by the National Academy of Sciences in 1961.

◄ **Drake helped devise the Voyager Golden Records, a 'message in a bottle' to aliens about life on Earth**

A design for life

With a list of distinguished scientists from across disciplines due to attend, Drake first had to organise the agenda of the conference. On a blackboard in the basement, he wrote all the factors that would need to be discussed to determine how common life was in the Universe. Each of these, he realised, could be expressed as a number and multiplied together to estimate the number of civilisations in the Universe that humanity could detect. This was to become the now famous Drake equation.

From 1966 to 1968, Drake lived in Puerto Rico, as director of Cornell's 305-metre-wide radio telescope at Arecibo, overseeing its transition from missile defence facility to astronomical tool. By the 1970s, Drake was not just listening for alien signals, but reaching out to distant civilisations. He worked with Sagan to produce both the Pioneer plaque and the Voyager Golden Records – pictorial depictions of humanity and our location in the cosmos. These were attached to the Pioneer and Voyager probes, just in case an alien lifeform should stumble across them out beyond the Solar System. In 1974, he again paired with Sagan to transform this same information into a radio signal that could be decoded by another intelligent race. On 16 November they used Arecibo's powerful transmitter to broadcast it towards globular cluster M13, where it will arrive in 25,000 years' time.

He served as director of the Carl Sagan Centre at the SETI Institute from 1984 to 2010, but continued to support many long-term SETI projects after his retirement. His dedication helped make SETI a legitimate scientific discipline and inspired the generations after him to continue the search.

BBC Sky at Night MAGAZINE

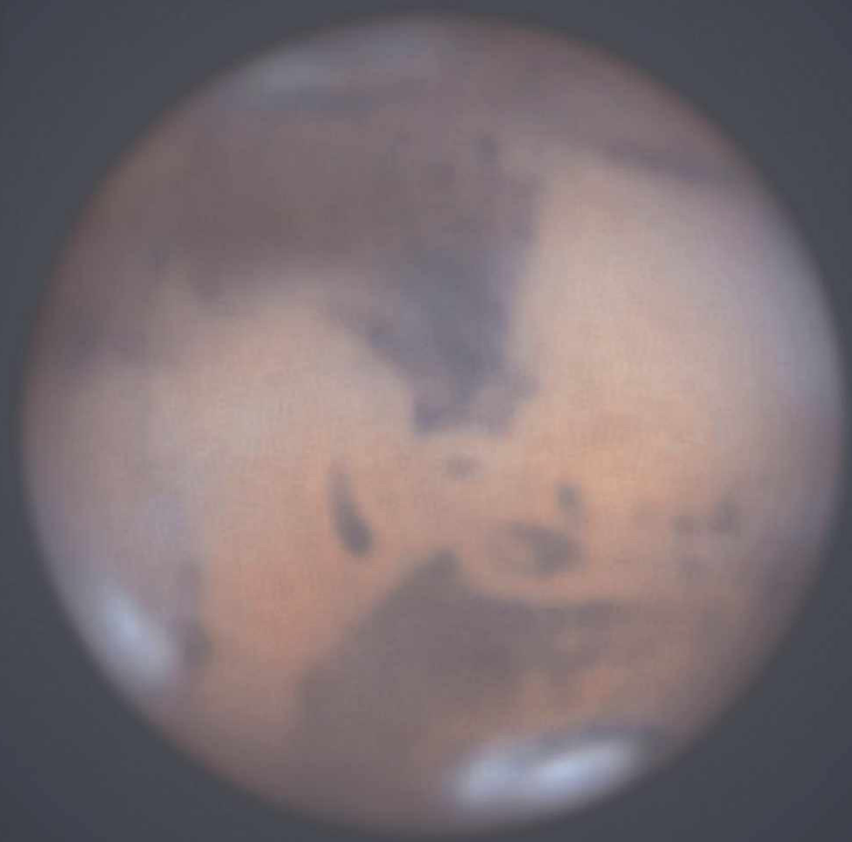
16-PAGE CENTRE PULLOUT

The Sky Guide

NOVEMBER 2022

GET READY FOR MARS

High above the mighty Orion, the Red Planet gets bigger and better each day as it approaches opposition



LEONIDS AT THEIR PEAK

Predicted brighter meteors go head to head with a nearby waning Moon

MEET ELECTRA

The Pleiades' leading light is our Star of the Month

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- ✦ Good librations: Mare Orientale visible
- ✦ Uranus at opposition: how to spot it
- ✦ Can you capture Mars's dim moons?

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

NOVEMBER HIGHLIGHTS

Your guide to the night sky this month

◀ Tuesday

1 This evening's 56%-lit waxing gibbous Moon sits 5° to the south of mag. +0.8 Saturn.

There are two first quarter Moons in November this year, today at 06:38 UT and on 30 November at 14:37 UT.

Friday

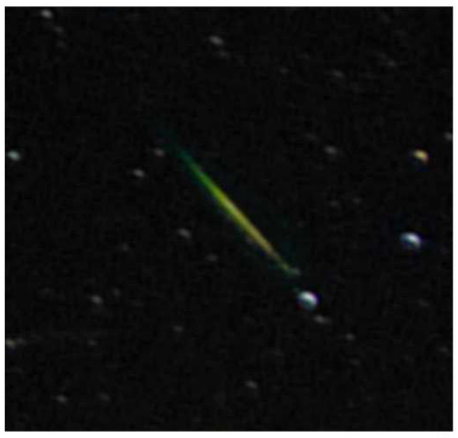
4 Your first opportunity to spot this month's Moonwatch target, the 70km crater Hainzel. It's close to the lunar evening terminator on the morning of 18 November, appearing on the terminator itself on 19 November.

Wednesday

9 The planet Uranus reaches opposition.

Thursday ▶

17 The annual Leonid meteor shower reaches its peak tonight and into the morning of 18 November. The 33%-lit waning crescent Moon is located within Leo at this time, causing some interference.



Friday ▶

18 Libration is relatively favourable for viewing Mare Orientale on this and the next few mornings.

Callisto passes near Jupiter's northern limb between 23:05 UT today and 00:15 UT on 19 November.

Family stargazing

Mars is getting bright and really easy to pick out in the night sky as it gets close to opposition on 8 December. Describe it as a bright, orange light in the sky and let your young astronomers try to find it for themselves. Its brilliance is a bit of a giveaway, but the colour is interesting too. Ask how you'd describe the colour. Mars only reaches this brilliance every two-and-a-bit years, due to the way both Earth and Mars orbit the Sun, so explain that this is a special time for the planet. If you have a telescope, take a look and ask what, if anything, can be seen. **bbc.co.uk/cbeebies/shows/stargazing**

Sunday

20 Ganymede is occulted by Jupiter starting at 17:27 UT as Europa's shadow is in transit. A virtual repeat of this event occurs on 27 November from 21:08 UT – see page 46 for more details.

Tuesday

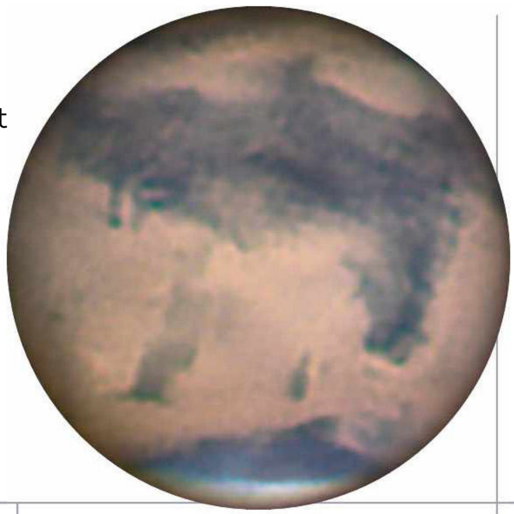
29 The 40%-lit waxing crescent Moon lies 8° to the east-southeast of magnitude +0.8 Saturn this evening.

PETE LAWRENCE X 6

Wednesday ▶

2 As Mars nears opposition next month, it shines at mag. –1.3 in the evening sky above the constellation Orion, appearing 15 arcseconds across through a telescope.

Europa and Ganymede transit Jupiter from 20:44 UT.



Thursday

3 The popular and easy to see clair-obscur effect known as the Jewelled Handle is visible this evening. This occurs when the lunar dawn light hits the peaks of the curved Jura mountain range, creating a light arc that extends into the lunar night.

Saturday

5 At 00:13 UT, you can see an 86%-lit waxing gibbous Moon lying 2.7° below mag. –2.6 Jupiter.

Sunday

6 A view of Jupiter through a telescope early this evening will reveal its giant moon Ganymede emerging from the planet's shadow. Ganymede reappears from 16:49 UT, 1.1 arcminutes east of the planet.

Monday

7 Over the next few nights dwarf planet Ceres will pass through the Leo Triplet: galaxies M65, M66 and NGC 3628. See page 47 for further details.

Thursday

10 Europa and Ganymede both transit Jupiter together this morning. Both moons will be in transit from 00:19 UT until 01:38 UT, Europa's shadow joining the party from 01:05 UT.

Friday

11 Magnitude –1.5 Mars sits just 5° from this morning's 92%-lit waning gibbous Moon. You will catch them at their closest at around 05:00 UT.

Sunday

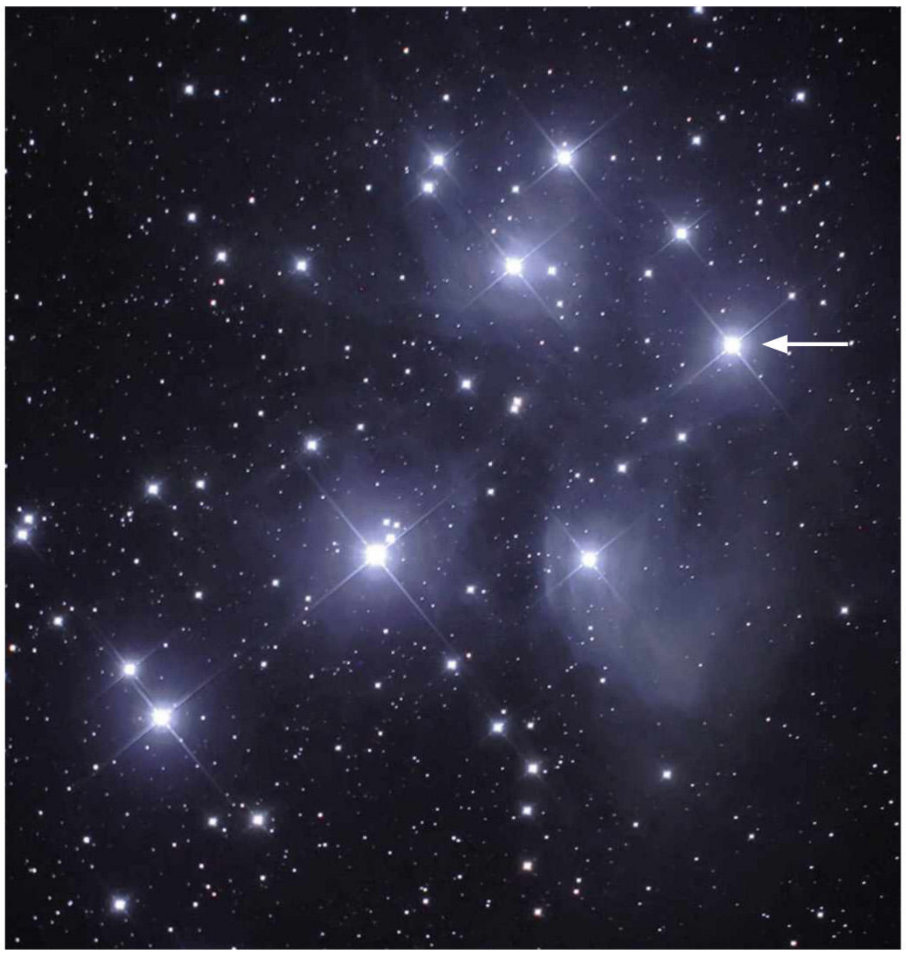
13 Mars reaches mag. –1.5 and appears 16 arcseconds across when viewed through a telescope.

Saturday ▶

19 This month's Star of the Month (see page 53) is Electra, one of the mythological sisters in the Pleiades open cluster. This beautiful cluster is at its highest at midnight, around 60° up, due south.

Wednesday

30 Just over a week from opposition, Mars now shines at mag. –1.8 and presents an apparent disc size of 17 arcseconds. From the centre of the UK it achieves an altitude of 60°.



NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

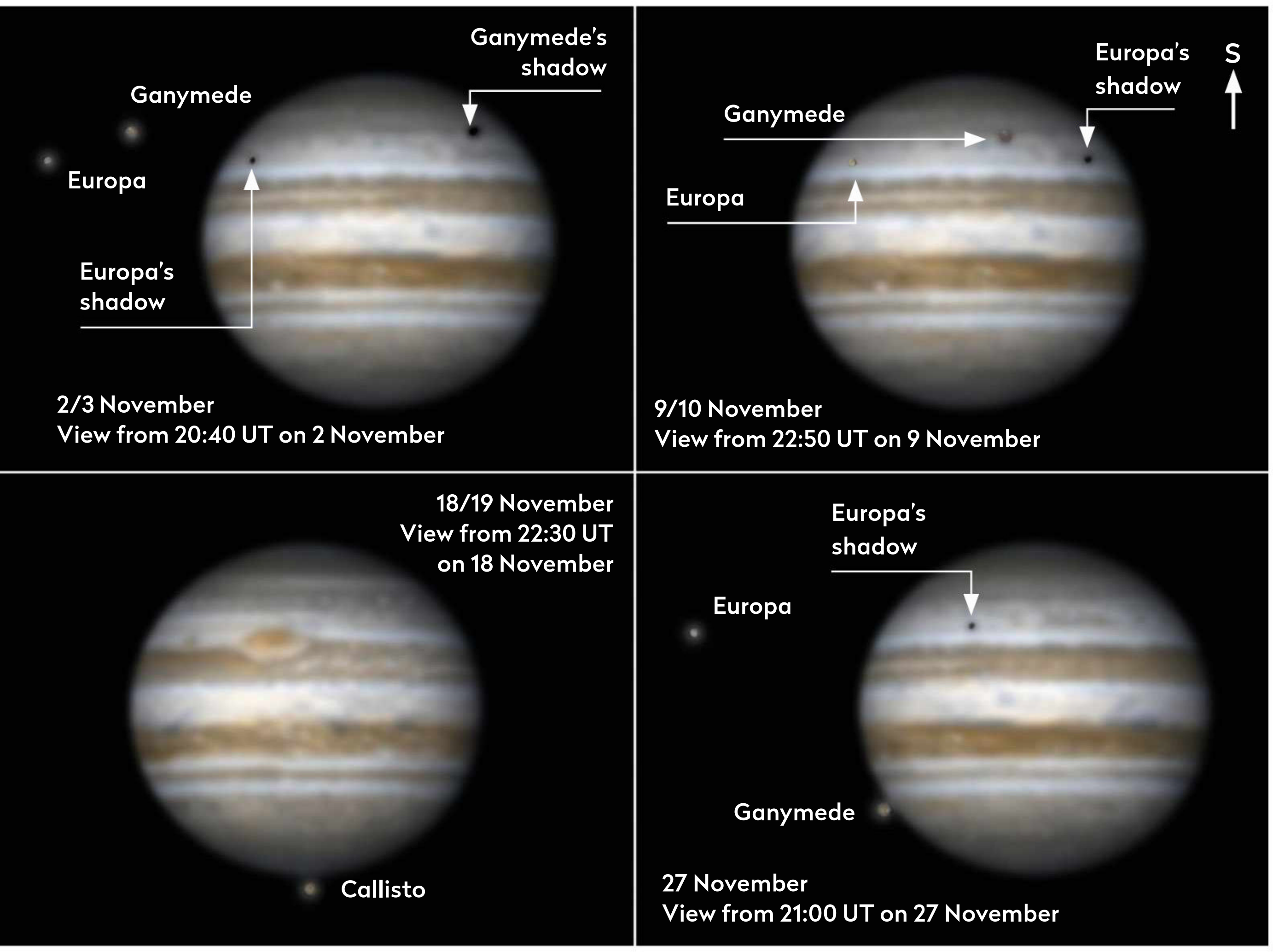
If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE The top sights to observe or image this month

DON'T MISS

Jupiter moon events

BEST TIME TO SEE: 2/3, 6, 10, 18/19 and 27 November



▲ **The Galilean moons and their shadows can be seen criss-crossing Jupiter all month**

Jupiter is well-placed throughout November, showing a wealth of atmospheric detail to those with larger instruments. But owners of smaller scopes can enjoy some of the amazing interactions between the planet and its four largest Galilean moons: Io, Europa, Ganymede and Callisto. These moons are bright and easily visible through smaller instruments as points of light. For those with larger-aperture scopes, it may be possible to perceive the moons as tiny discs, the apparent diameters being 1.2 arcseconds for Io, 1.0 arcseconds for Europa, 1.7 arcseconds for Ganymede and 1.5 arcseconds for Callisto.

On 2 November, Europa and Ganymede can both be seen starting to transit the Jovian disc from 20:44 UT. Io is very close to the planet's western limb at this time, being occulted by Jupiter a few minutes later at 20:50 UT as the other two moons progress with their transit. Europa and Ganymede then appear to race across Jupiter's disc, Europa eventually catching Ganymede and taking the lead, courtesy of its closer, faster orbit. At 22:30 UT, Europa's shadow begins its transit, Europa, its shadow and Ganymede all appearing on Jupiter's disc until the end of Europa's transit at 23:15 UT. Ganymede's shadow also makes an appearance at 00:21 UT on 3 November, forming a double shadow transit with Europa's shadow until 01:00 UT when the smaller shadow leaves the planet's disc.

On 6 November, an early view of Jupiter through a telescope will show the giant moon Ganymede emerge from Jupiter's shadow 1.1 arcminutes east of the planet at 16:49 UT. For larger instruments, it may be possible to resolve the curving shadow across Ganymede's tiny disc.

Europa and Ganymede are in transit again on the morning of 10 November. Between 01:06 UT and 01:38 UT, Europa, its shadow and Ganymede can be seen transiting at the same time.

Between 23:05 UT on 18 November and 00:15 UT on 19 November the outer moon Callisto will appear to almost touch Jupiter's northern limb. It will appear closest to Jupiter at 23:40 UT.

On the evening of 27 November from 21:00 UT, Ganymede will be occulted by Jupiter. Starting at 21:08 UT, it will take 10 minutes for Ganymede to fully disappear. Again, large telescopes set up for planetary imaging may get a shot of Ganymede's resolved disc. Short, high-frame-rate sequences may even be able to capture the event as a timelapse.

Catch Ganymede emerging from eclipse on 6 November, just as the sky is darkening

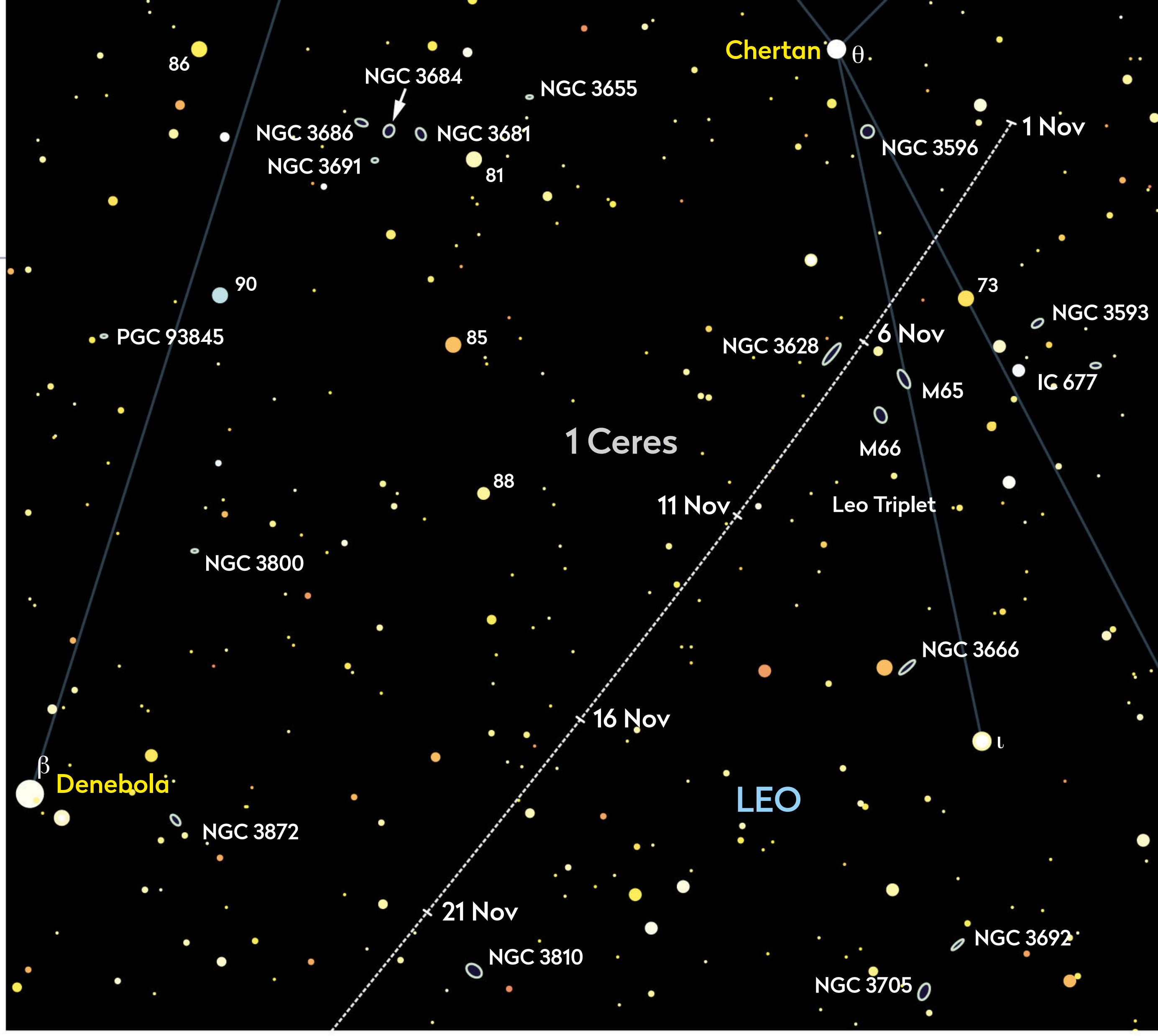
ALL PICTURES: PETE LAWRENCE

Ceres through the Triplet

BEST TIME TO SEE: 1–10 November

Dwarf planet Ceres is moving through the constellation of Leo this month, appearing like a mag. +8.8 star but moving over time. On the morning of 1 November at around 03:00 UT it sits 19 arcminutes south of the mag. +6.3 star HIP 54688. From here it makes its way east-southeast through Leo, toward, through and beyond the famous Leo Triplet, a collection of three distinctive galaxies – mag. +9.6 M65, mag. +9.7 M66 and mag. +10.4 NGC 3628 – near the Lion's back leg.

At 03:00 UT on the morning of 3 November, Ceres sits 1.5° south of Chertan (Theta (θ) Leonis) and 1.2° west-northwest of the Triplet, moving toward the Triplet. On the morning of 6 November it begins its passage between the northern member NGC 3628 and the southern pair M65 and M66. NGC 3628 is known as the Hamburger Galaxy, its distinctive almost rectangular appearance, with a dark dust lane running along its centre, appearing like the popular fast food seen side-on.



▲ **The passage of dwarf planet Ceres through the Leo Triplet this month; its positions marked at 00:00 UT on the dates shown. This area of sky isn't well-placed until around 03:00 UT**

The passage is brief, Ceres taking a day to cross the apparent width of NGC 3628. On 7 November at 03:00 UT, it lies around 9 arcminutes from the core of this galaxy. A view of the general area on the morning of 8 November shows Ceres just east of the Triplet and now east-southeast of NGC 3628. At 03:00 UT, it appears separated from NGC 3628 by about the same distance as that between M65 and M66.

Ceres continues east-southeast, a bright Moon now interfering with the view. On 21 November, Ceres lies 40 arcminutes north of mag. +11.4 galaxy NGC 3810.

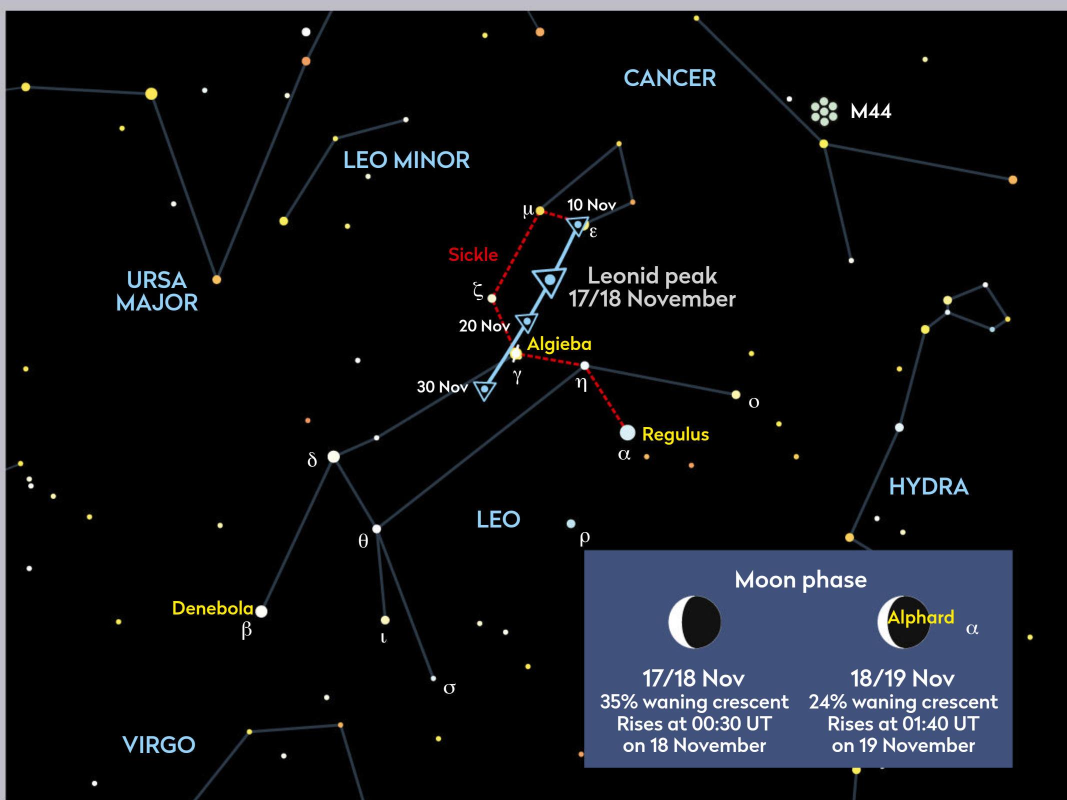
Leonid meteor shower

BEST TIME TO SEE: Nights of 17/18 and 18/19 November

The Leonid meteor shower is a popular annual shower despite its relatively low peak Zenithal Hourly Rate (ZHR) of 15 meteors per hour. Bear in mind that this value is for optimal viewing conditions with the shower radiant directly overhead. As conditions aren't optimal this year and the radiant achieves a maximum altitude of just 58° under dark sky conditions, the visual rate – the number you'll actually see – will be lower than this.

The shower's popularity is in part due to a periodic increase in its ZHR every 33 years. At such times the Leonids may produce a storm-level display of 1,000–100,000 meteors per hour. The next interesting period begins around 2032–2033, so we are in between 'storms' at present. However, a prediction has been made for a moderate ZHR enhancement between 05:50 UT and 06:10 UT on the morning of 19 November, as the sky is brightening. Brighter than average meteors are also predicted. A 33%-lit waning crescent Moon in southeast Leo will interfere somewhat on the morning of 18 November.

Leonid meteors are swift, entering the atmosphere at 77km/s. Trails appear to emanate from the shower radiant conveniently located in the head of Leo the Lion, within the Sickle asterism.



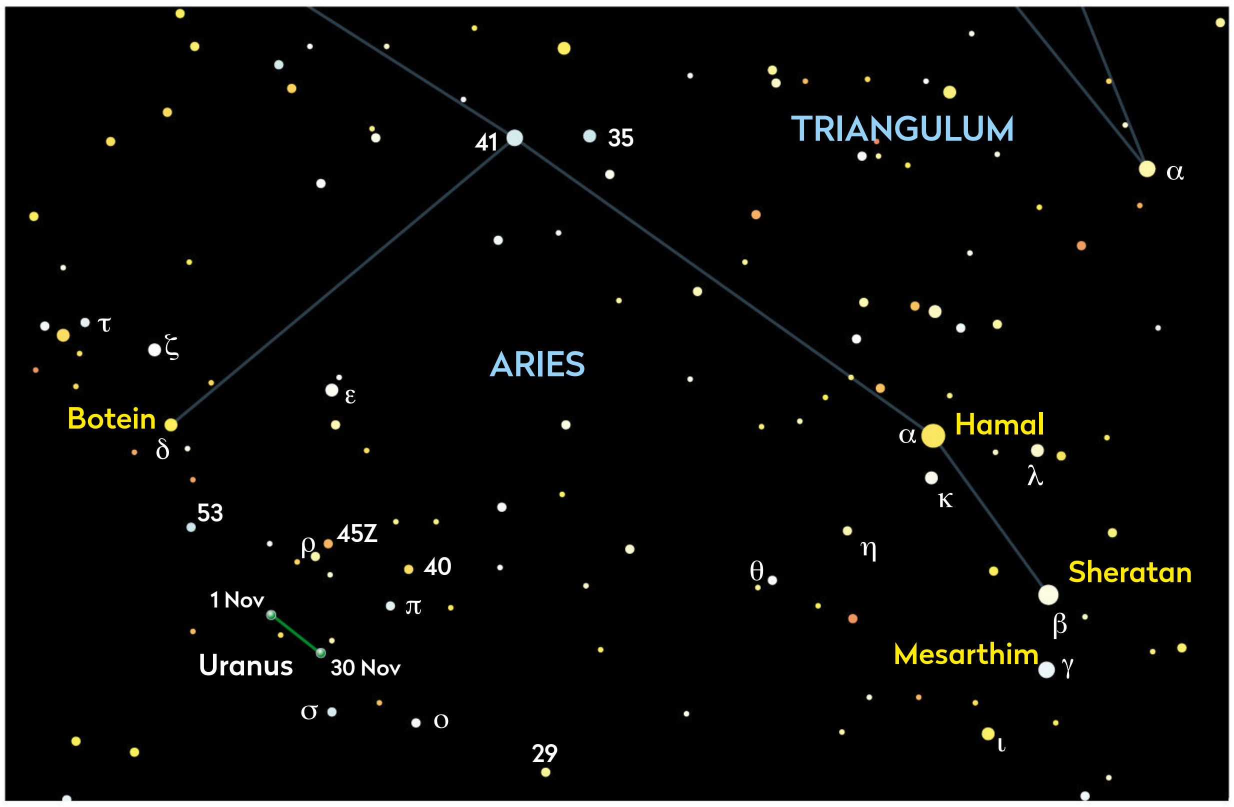
▲ **Look to the Sickle asterism in Leo for the radiant of the Leonids**

THE PLANETS Our celestial neighbourhood in November

PICK OF THE MONTH

Uranus

Best time to see: 9 November, 00:00 UT
Altitude: 54°
Location: Aries
Direction: South
Features: Greenish hue, atmospheric banding, moons
Recommended equipment: 150mm or larger

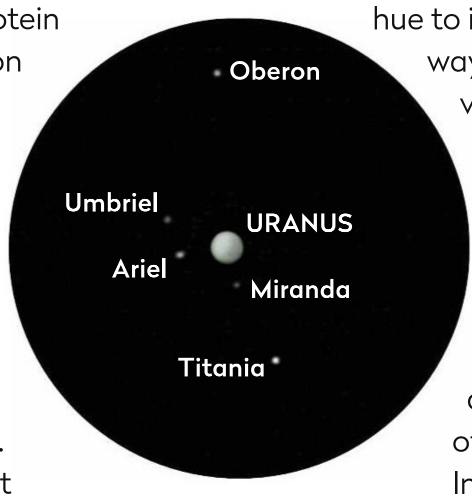


▲ Use stars in Aries to locate mag. +5.6 Uranus. A telescope will reveal its greenish colour

Uranus reaches opposition on 9 November, but unlike our nearer Solar System neighbours Mars, Jupiter and Saturn, its position in the opposite part of the sky to the Sun produces only a very subtle improvement in the general appearance of the planet, something that it shares with its outer neighbour, Neptune.

We normally comment on the fact that Uranus, being able to reach a peak altitude of 53° when due south, is the best-placed planet to observe from the UK. However, we're happy to report that this is currently untrue, as Mars is able to appear higher this month.

Uranus is shining at mag. +5.6 this month and should theoretically be visible from a dark site using nothing more than your eyes. In practice this can be quite a hard task to achieve but if you want to give it a go, first identify Botein (Delta (δ) Arietis) and Epsilon (ε) Arietis, which shine at magnitudes +4.3 and +4.6 respectively. Imagine them as the side of an equilateral triangle, with the third vertice to the southwest. This is marked by two dim stars, mag. +5.6 Rho (ρ) and mag. +5.8 45Z Arietis. At the start of November these close stars (21 arcminutes between them) point south to Uranus.



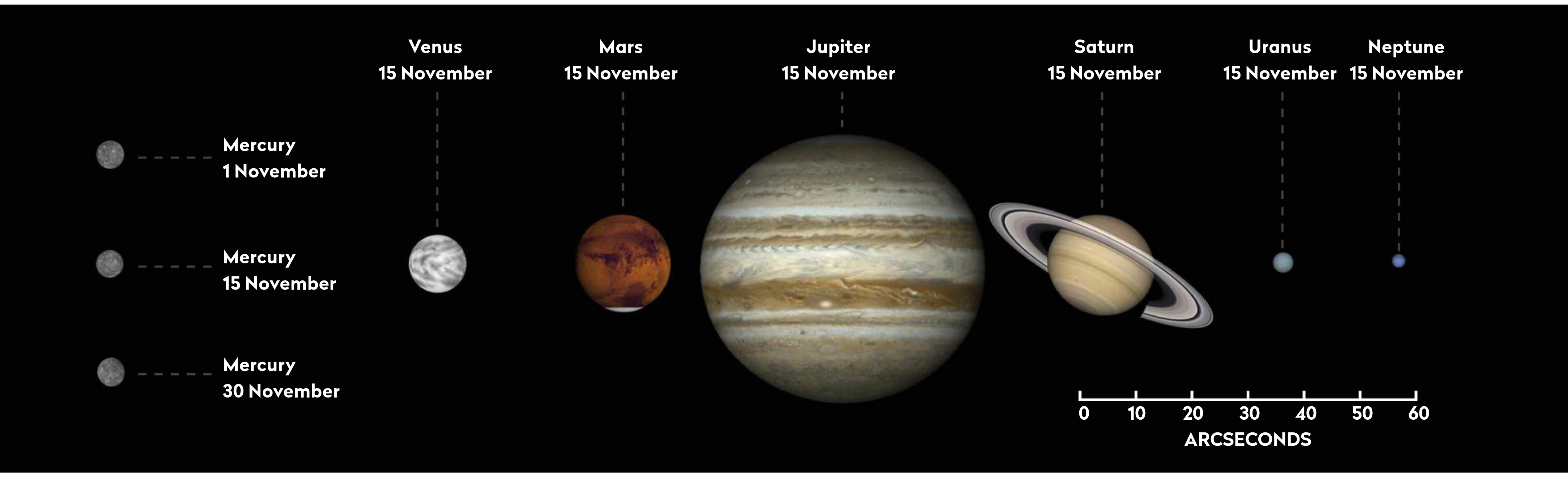
▲ Uranus and its brighter moons, imaged in January of this year

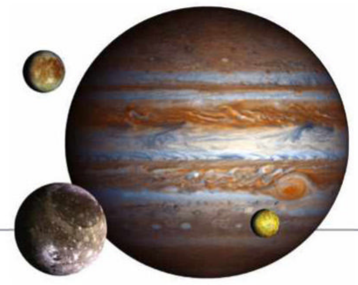
Through a telescope, the planet has a 3.8-arcsecond disc with a distinctive green hue to it, but there's little in the way of detail that can be seen visually. Imaging setups may be able to detect banding on the planet using filters that let longer (red) wavelengths pass. Here you'll need to be patient and collect a considerable number of frames for stacking. In addition, extended exposures may be used to reveal the planet's brighter moons, Miranda, Ariel, Umbriel, Titania and Oberon. Miranda is close to the planet and a tough target.

PETE LAWRENCE X 2

The planets in November

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mars

Best time to see:
30 November, 00:40 UT
Altitude: 62°
Location: Taurus
Direction: South

Mars rises around 18:45 UT at the start of November and is able to reach its highest position in the sky, due south, in darkness all month long. Approaching opposition on 8 December, it is now a very attractive planet to view through a telescope. On 1 November Mars presents a disc with an apparent diameter of 15 arcseconds and shines at mag. –1.2. By the end of the month these values will have increased significantly, Mars presenting an apparent disc size of 17 arcseconds and appearing very bright at mag. –1.8. A bright 89%-lit waxing gibbous Moon lies near the planet on the evening of 11 November.

Jupiter

Best time to see:
1 November, 21:30 UT
Altitude: 35°
Location: Pisces
Direction: South

Bright evening planet Jupiter remains well-positioned all month. On the night of 4/5 November, it is joined by an 86%-lit waxing Moon lying 2.7° to the south. On 1 November Jupiter shines at mag. –2.7, which only drops to –2.5 by the end of the month. It reaches its highest position of 35° as seen from the centre of the UK, under dark sky conditions all month. Jupiter currently lies southeast of the Circlet asterism in Pisces.

Saturn

Best time to see:
1 November, 18:50 UT
Altitude: 21°
Location: Capricornus
Direction: South

Shining at mag. +0.8 at the start of November, Saturn reaches its peak altitude, due south, under dark sky conditions for much of the month, although the evening twilight encroaches towards the end of November. A 55%-lit waxing Moon lies near Saturn on 1 November and as a 39%-lit waxing crescent on the evening of 29 November.

Neptune

Best time to see:
1 November, 21:00 UT
Altitude: 33°
Location: Aquarius
Direction: South

Neptune is well-placed for UK observation, able to reach its peak altitude, due south, under dark sky conditions all month long. Mag. +7.9 Neptune and –2.5 Jupiter appear 6.1° apart mid-month.

Not well-placed for observation this month:

Mercury

At the start of November, Mercury shines at around mag. –1.0 but rises less than 30 minutes before the Sun. It reaches superior conjunction on 8 November, lining up with the Sun on the far side of its orbit. Its emergence into the evening sky isn't particularly favourable, the planet being low after sunset and setting not long after the Sun.

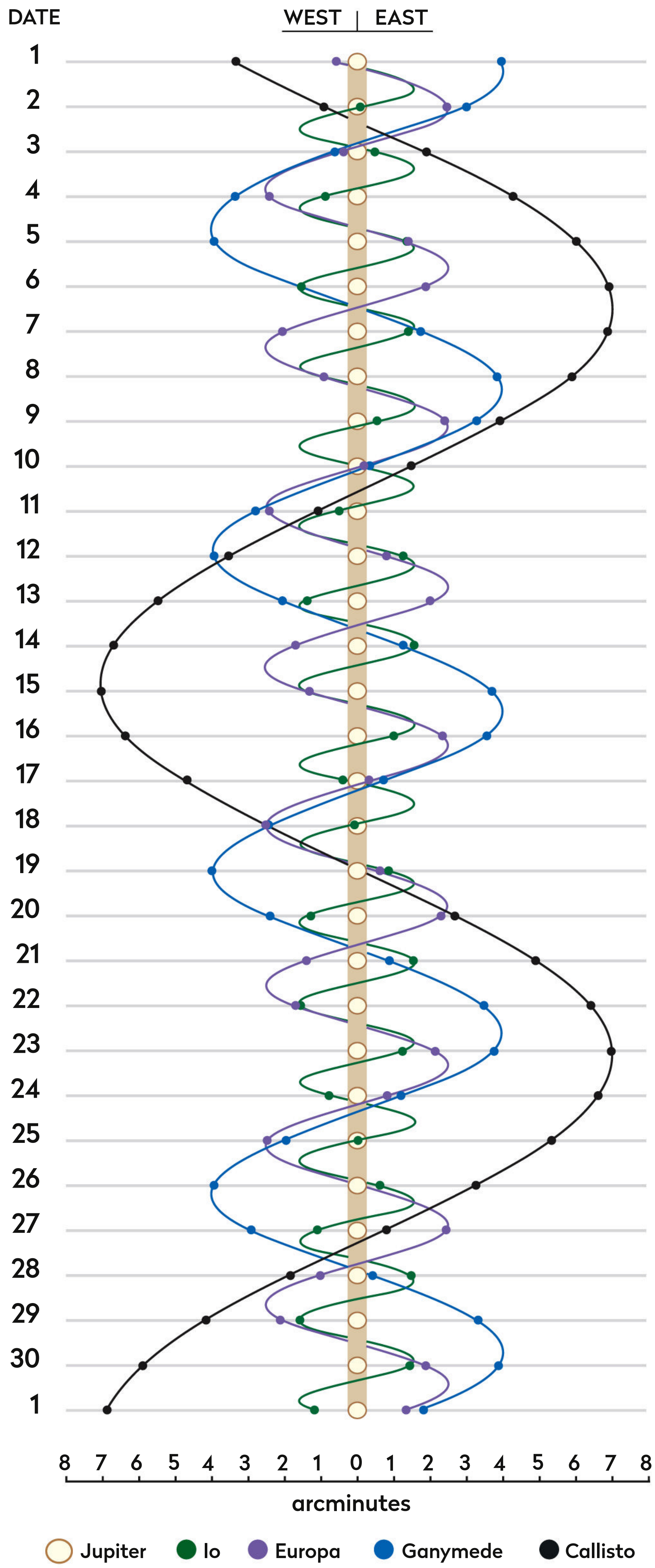
Venus

Venus passed superior conjunction on 22 October and remains very close to the Sun at the start of November. It sets just 30 minutes after the Sun on 30 November and will probably remain unseen right through the month.

More ONLINE
Print out observing forms for recording planetary events

JUPITER'S MOONS: NOV

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – NOVEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

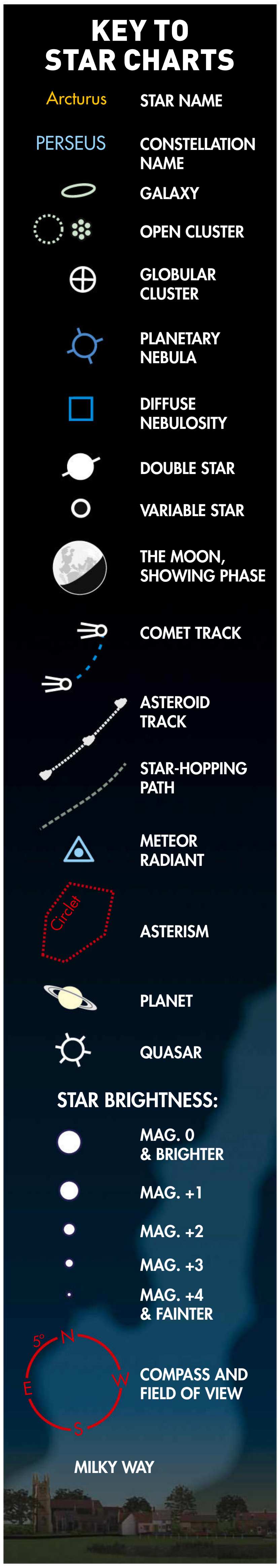


CHART: PETE LAWRENCE

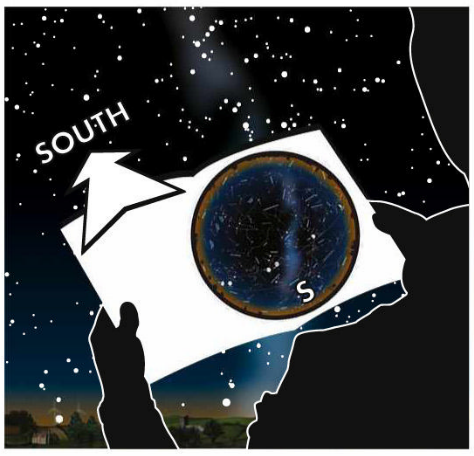
When to use this chart

1 November at 00:00 UT
15 November at 23:00 UT
30 November at 22:00 UT

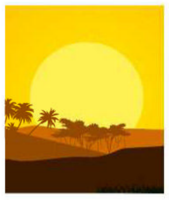
On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.



Sunrise/sunset in November*



Date	Sunrise	Sunset
1 Nov 2022	07:09 UT	16:38 UT
11 Nov 2022	07:28 UT	16:20 UT
21 Nov 2022	07:46 UT	16:05 UT
01 Dec 2022	08:03 UT	15:55 UT

Moonrise in November*

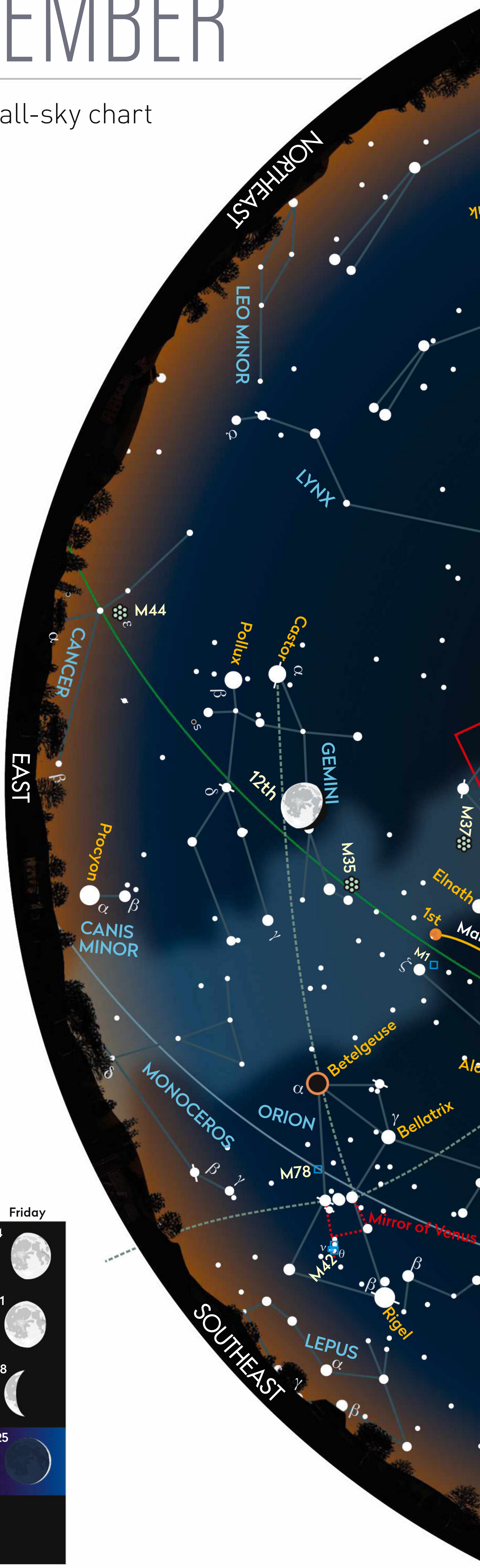
Moonrise times

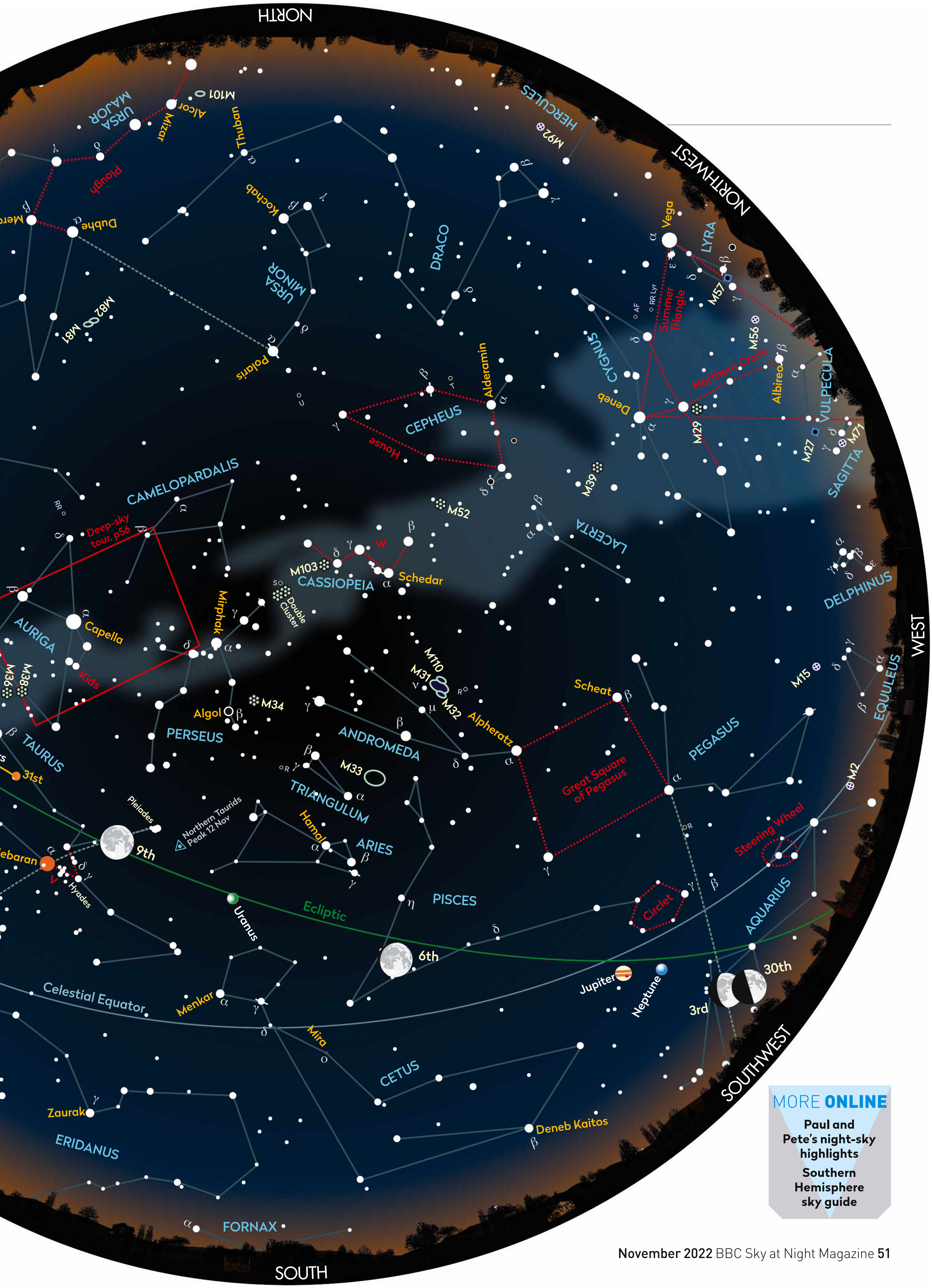
1 Nov 2022, 14:49 UT	17 Nov 2022, --:-- UT
5 Nov 2022, 15:45 UT	21 Nov 2022, 04:15 UT
9 Nov 2022, 16:39 UT	25 Nov 2022, 10:14 UT
13 Nov 2022, 19:26 UT	29 Nov 2022, 13:16 UT

*Times correct for the centre of the UK

Lunar phases in November

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
			1	2	3	4
5	6	7	8 FULL MOON	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23 NEW MOON	24	25
26	27	28	29	30		



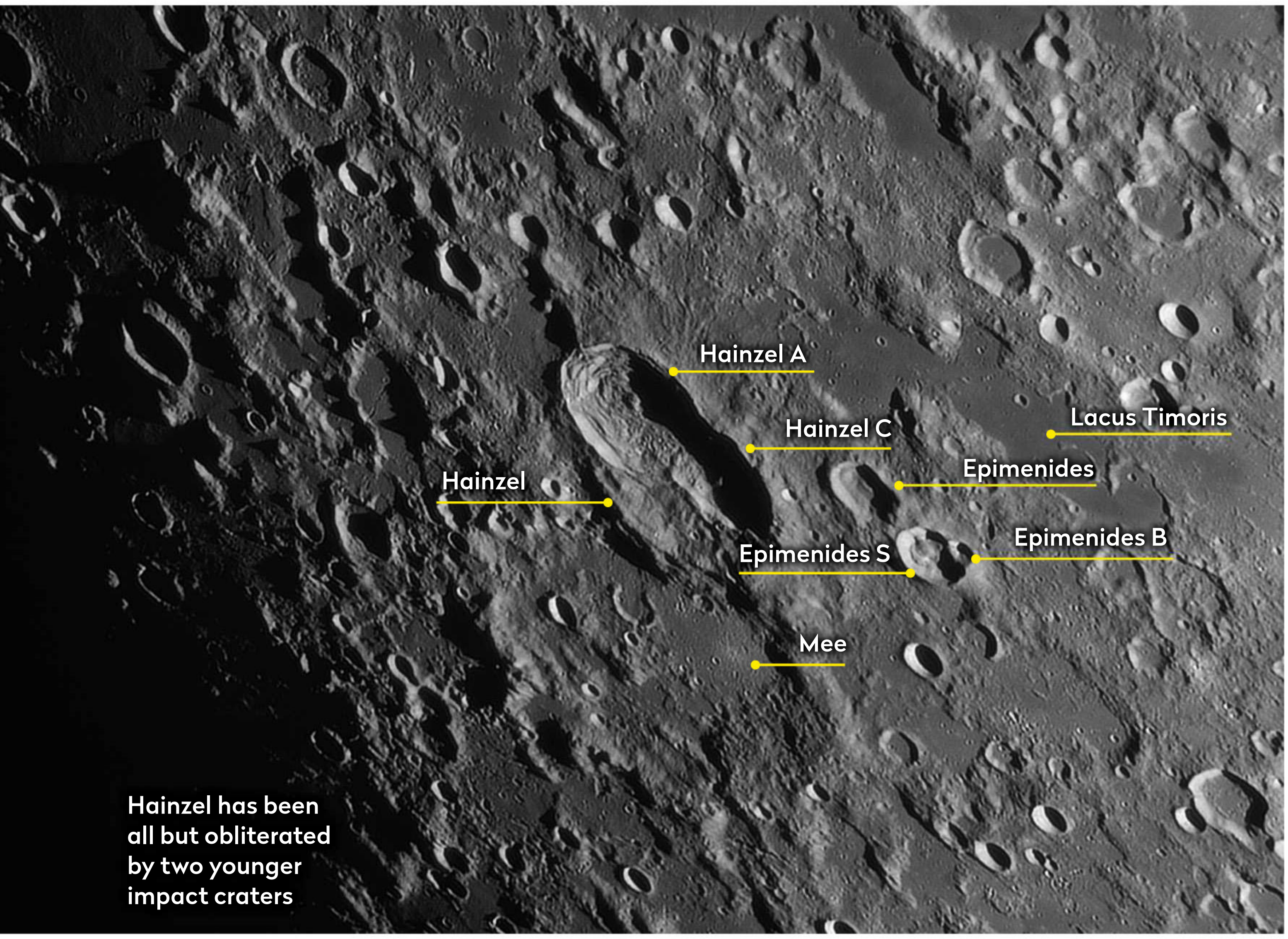


MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

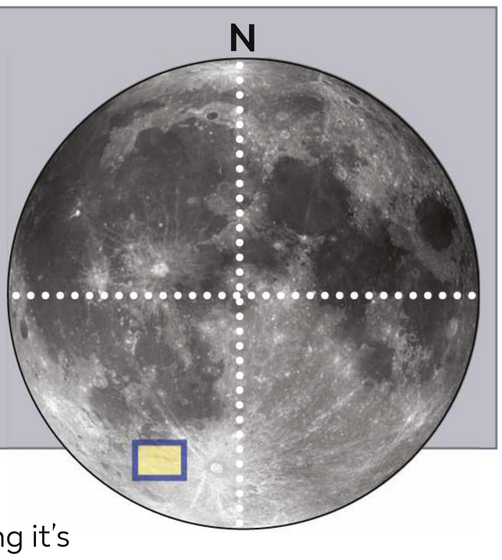
MOONWATCH
November's top lunar feature to observe



Hainzel has been all but obliterated by two younger impact craters

Hainzel

Type: Crater
Size: 70km
Longitude/Latitude: 33.5˚ W, 41.2˚ S
Age: Around 3.9 billion years
Best time to see: Three days after first quarter (4 November) or two days after last quarter (18–19 November)
Minimum equipment: 50mm refractor



You could sum up crater **Hainzel** by saying it's large, easy to find but difficult to see. Let's address these in order. With a diameter of 70km, Hainzel is certainly big, just 16km smaller than the bright ray crater Tycho that is located 500km to its east. Then there's the fact that finding Hainzel is easy due, ironically, to the reason that it's tricky to see. It is overlaid by two other large craters: 24km **Hainzel A** to the north and 18km **Hainzel C** to the northeast.

The degree of overlap is severe. Co-joined themselves, Hainzel C and A obliterate most of Hainzel, overlying in excess of 50 per cent of its area. The structures that form this interesting trio are best seen under oblique illumination, in particular when the morning terminator is near, three days after first quarter. The old rugged, eroded surface of Hainzel is in stark contrast to the impressive terraced nature of Hainzel A to the north. **Hainzel A** is a much younger formation – obviously because it overlaps Hainzel – but its appearance is youthful too, with much of its internal rim terracing appearing sharp and well defined. This is a lovely feature to observe with a large telescope or using a high-resolution imaging setup, as there is a huge amount of intricate detail to be captured.

Like Hainzel A, **Hainzel C** has a central mountain peak, but its appearance is more like Hainzel: eroded, and ill-defined. Hainzel C's rim is irregular in shape and the whole crater looks as if someone has sanded it smooth. The transition between Hainzel A and C isn't particulary well defined, the internal terraces of Hainzel A forming a rough border. The sharp southern edges of both craters do manage to delineate well from the rough formation of Hainzel to the south.

The trio is located in a rough highland region of the Moon and the surrounding area is littered with craters of all shapes and sizes. To the immediate south is the colossal walled plain of **Mee**, an ancient, eroded formation 133km in diameter. Although Mee isn't that distinct, its general form is fairly easy to work out. When you bear in mind that it is twice the diameter of Hainzel, you realise just how much of the latter has been compromised due to being overlaid by Hainzel A and Hainzel C.

Heading east from Hainzel C brings you to another old but remarkably well-preserved crater in the form of 27km **Epimenides**. Estimated to be over 3.9 billion years old, the rim of Epimenides remains impressively sharp. It lies next to a similar-sized formation **Epimenides S**, which can appear quite complex under low illumination thanks to several smaller overlying craters.

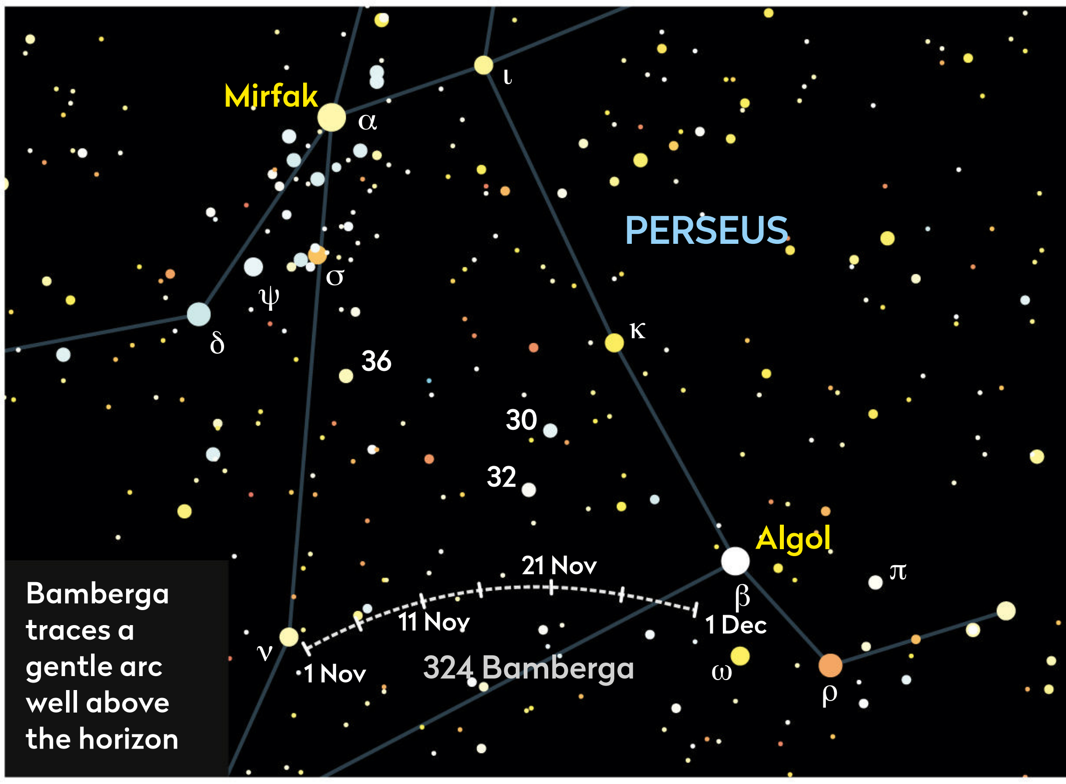
Hainzel is easy to find but difficult to see as it's overlaid by two large craters

To the north of Epimenides and northeast of the Hainzel, A and C trio, lies the irregular, dark form of **Lacus Timoris** or Lake of Fear. This region is around 50km wide (north–south) at its widest point and 150km in length. Filled with lava, its dark, irregular shape stands out rather well against the brighter lunar highlands that surround it.

PETE LAWRENCE X 3

COMETS AND ASTEROIDS

324 Bamberga is well-placed all month as it reaches opposition in Perseus



Asteroid 324 Bamberga reaches opposition on 21 November, shining at 9th magnitude in the constellation of Perseus. It is fortuitously well placed at the moment, the asteroid describing a north-bowing arc between mag. +3.8 Nu (ν) Persei and eclipsing binary Algol (Beta (β) Persei).

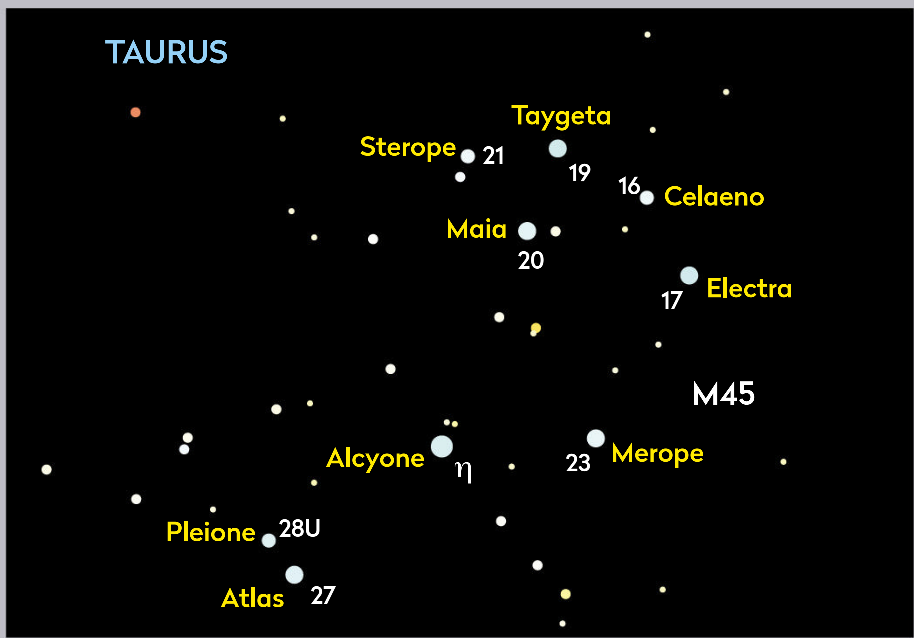
324 Bamberga begins the month 20 arcminutes southwest of Nu Persei, thereafter heading west and very gently north, before curving southwest towards the quadrilateral of stars formed by Algol, Omega (ω), Pi (π) and Rho (ρ) Persei. It ends the month a degree east and very slightly south of Algol. Over this period its brightness hardly varies, starting and ending the month at mag. +9.2, increasing fractionally to +9.1 in the middle of the month.

Despite being the 324th officially recognised asteroid, Bamberga is quite large. With a mean diameter of 227km, it's in the top 20 largest asteroids within the main belt. It also has an eccentric orbit that takes it out as far as 3.59 AU from the Sun and in as close as 1.77 AU. This creates a considerable variation in its opposition magnitude, reaching mag. +8.0 when conditions are favourable, allowing it to become the brightest of its class – Bamberga being a C-type, carbon-rich asteroid. Favourable, near-perihelion oppositions occur with a periodicity of 22 years, and the next is due in 2035 when the asteroid will reach mag. +8.1 in September of that year. Bamberga rotates once every 29.43 hours, a long period for such a large asteroid. It's carbon-rich makeup gives it a low reflectivity of just 6%. It was discovered by the prolific Austrian asteroid hunter, Johann Palisa in 1892 and is named after Bamberg, a town in southern Germany.

STAR OF THE MONTH

Electra (17 Tauri), third-brightest star of the Pleiades

▼ Electra is one of the hot, blue stars that dominate the famous cluster



The Pleiades, M45 are a mainstay of the autumn night sky, an easy-to-find naked-eye bright cluster in the northwest corner of Taurus the Bull. The basic shape of the cluster is distinctive, resembling a box with a handle, reminiscent of part of the Plough asterism. The star furthest from the 'handle' is Electra, one of the named members of this cluster which represent the Seven Sisters of Greek mythology. The parents are present too: Atlas, the handle star furthest from the box, and Pleione, the dimmer one above it.

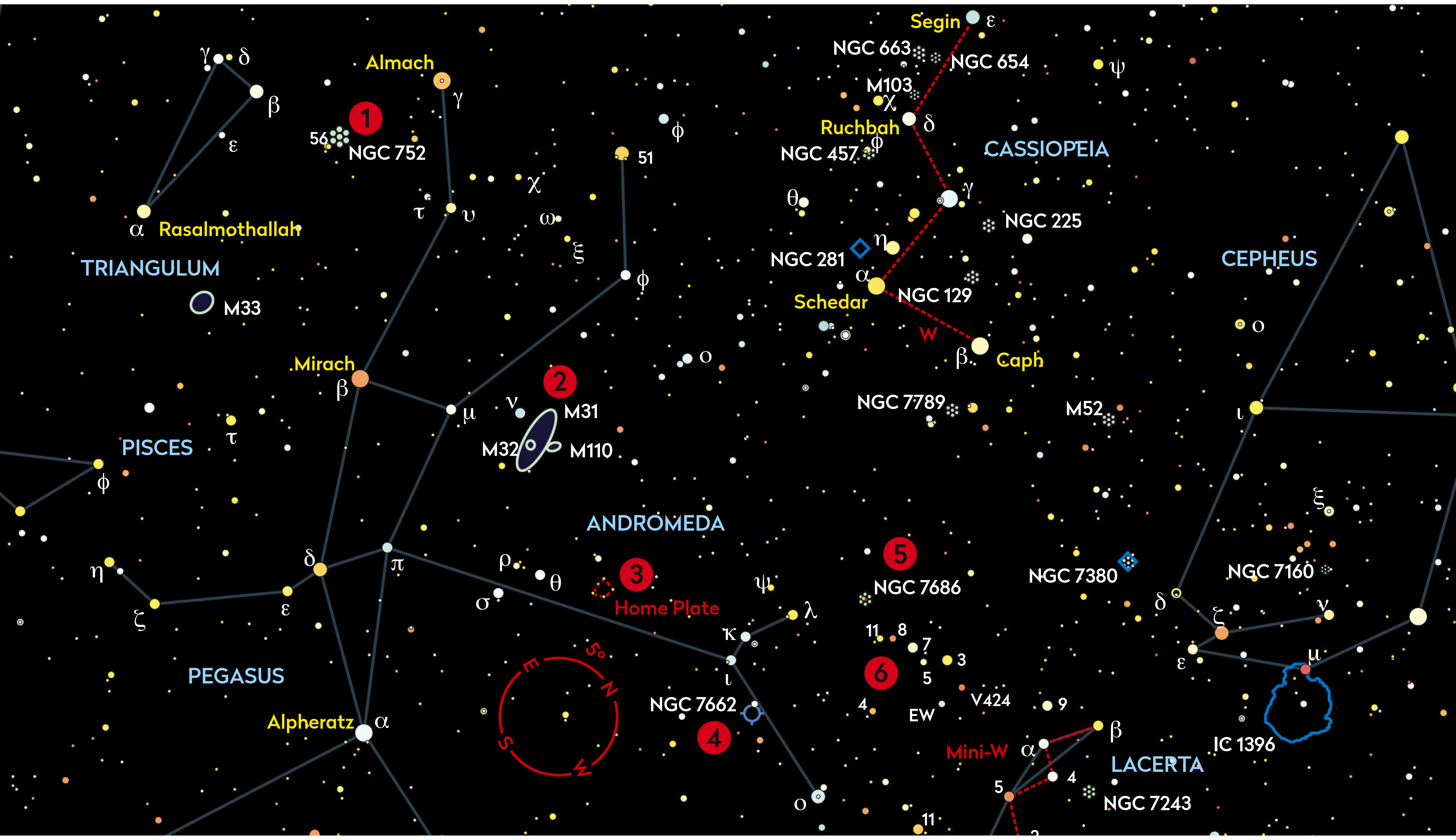
Electra is a blue-white star with a spectral type B6 IIIe. 'B6' indicates the star's colour and temperature being around 14,000K. The 'III' indicates that it's a normal giant, while the 'e' reveals that its spectrum has emission lines present as well as the more commonly seen dark absorption lines.

Electra is estimated to be around 400 lightyears distant, 44 lightyears closer than the centre of the Pleiades. It shines at mag. +3.7 and is interesting in that it rotates very fast. The Sun takes about 25 days to rotate at the equator and 35 days at the poles, a rotation speed of around 2km/s. Electra has a projected rotational velocity of 181km/s. However, the star's rotational axis is inclined to our line of sight by an estimated 46.8° and if you were to 'square up' Electra so that its rotational axis was at right angles to our line of sight, the rotational velocity would be around 320km/s. This rapid speed of rotation will flatten the star into an oblate shape. A disc of ejected material surrounds the star.

Electra is estimated to be six times larger than the Sun and around 1,225 times more luminous.

BINOCULAR TOUR With Steve Tonkin

Lie back and look straight up as Andromeda is this month's hunting ground



1. NGC 752 and 56 Andromedae

10x50 Put mag. +3.0 Beta (β) Trianguli at the south of the field of view and NGC 752 should appear near the north, just to the left of a close pair of 6th-magnitude orange stars (56 Andromedae). Unusually, the stars are yellowish (we normally expect hot blue-white stars in an open cluster), and this hints at its great age: nearly two billion years old! You should be able to resolve at least a dozen of these stars. ☐ **SEEN IT**

2. M31

10x50 Start with the mag. +2.1 yellow star Mirach (Beta (β) Andromedae) at the southeast of the field of view and find mag. +3.9 Mu (μ) Andromedae toward the other edge. Place Mu where Mirach was and the elliptical shape of M31 will be where Mu was. From a dark site you should notice that the galaxy extends about halfway across the field of view, and you may also see the two companion galaxies, M32 and M110. ☐ **SEEN IT**

PETE LAWRENCE X 3

3. The Home Plate

10x50 Locate the little triangle of mag. +4.6 Theta (θ), mag. +5.2 Rho (ρ) and mag. +4.5 Sigma (σ) Andromedae and pan 2.5° (about half a 10x50 field of view) northwest from Theta, where you'll find an irregular pentagon of yellowish 7th-magnitude stars. It covers an area about 0.5° x 0.75° and looks just like the home plate on a baseball field, a similarity for which the asterism is named. ☐ **SEEN IT**

4. NGC 7662

15x70 Identify mag. +4.3 Iota (ι) Andromedae and scan 2° west to 13 Andromedae. You'll find NGC 7662 – also known as the Blue Snowball Nebula – half a degree to the south-southwest. It looks like an 8th-magnitude star, but 70mm (or larger, if you have them) binoculars should help to bring out the blue-green tint that distinguishes it from the surrounding, mostly white, stars. You may find that its colour is more obvious if you defocus your binoculars very slightly. ☐ **SEEN IT**

5. NGC 7686

10x50 Find mag. +4.1 Kappa (κ) and mag. +3.9 Lambda (λ) Andromedae and extend a line joining them the same distance northwards, to an obvious pair of orange stars, the brighter of which is mag. +6.2. Relax your eyes and the 15-arcminute diameter glow of the background cluster will become visible, but you'll need to switch to larger binoculars if you want to be able to resolve more than another three individual stars. ☐ **SEEN IT**

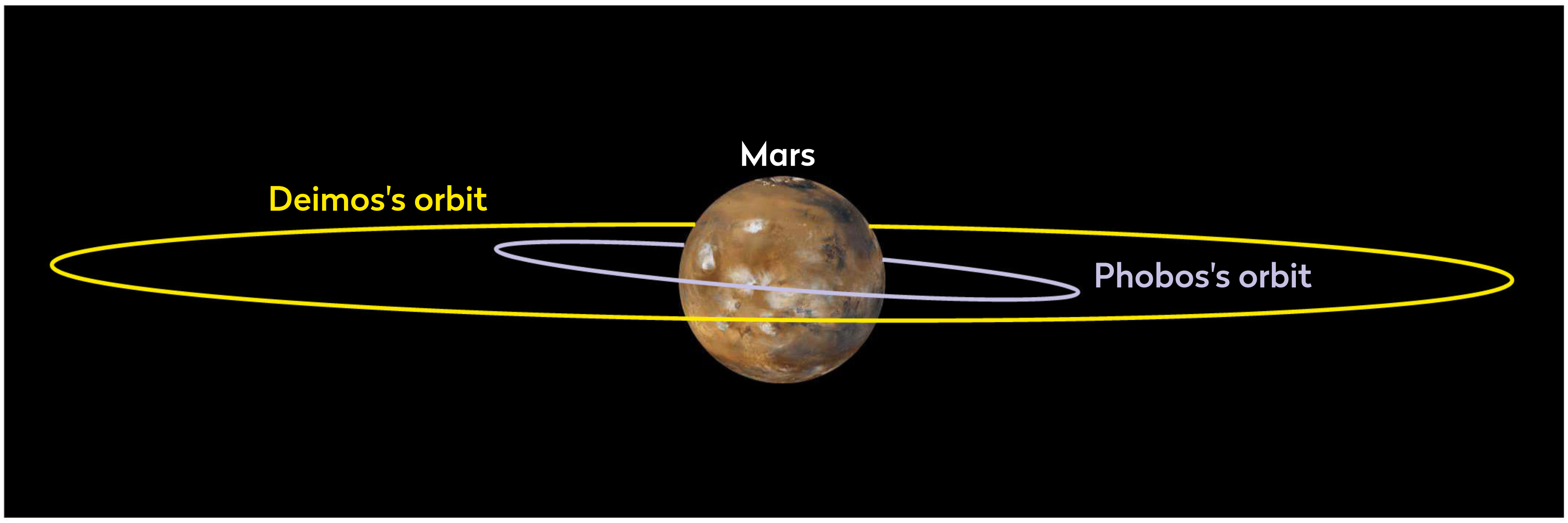
6. Northwest Andromeda starfield

10x50 If you like coloured stars, you'll love this bit of sky. In a region of less than 4°, you'll see seven 5th-magnitude stars from the brilliant blue-white of EW Lacertae, to the yellow-white of 7 Andromedae and the more orange 11 And, 3 And and V424Lac, to the sultry orange-red of 4 And and 8 And. It's all against a glorious Milky Way background! ☐ **SEEN IT**

☑ Tick the box when you've seen each one

THE SKY GUIDE CHALLENGE

Mars is getting closer, but can you photograph its dim moons, Phobos and Deimos?



▲ **The relative sizes of the moons' orbits. At elongation, Phobos appears one Mars diameter from the planet; Deimos is three Mars diameters**

As Mars approaches opposition on 8 December, its brilliance and position in the night sky will mean it will certainly be the centre of attention. Reaching opposition every 2.1 years, Mars is a tricky planet to get on with. Just as you're starting to advance in terms of observing its features, it moves away from Earth again, until the next opposition when you need to relearn your techniques! One skill to learn is how to capture the two dim Martian moons, Phobos and Deimos, the subjects of this month's challenge.

Mars oppositions are special and a time to make the effort to push the limits of your observing and imaging skills. Some oppositions are better than others and 2022's, although not the best, is good for those of us in the Northern Hemisphere, because the planet will be high in our sky. Its closest approach falls on 1 December.

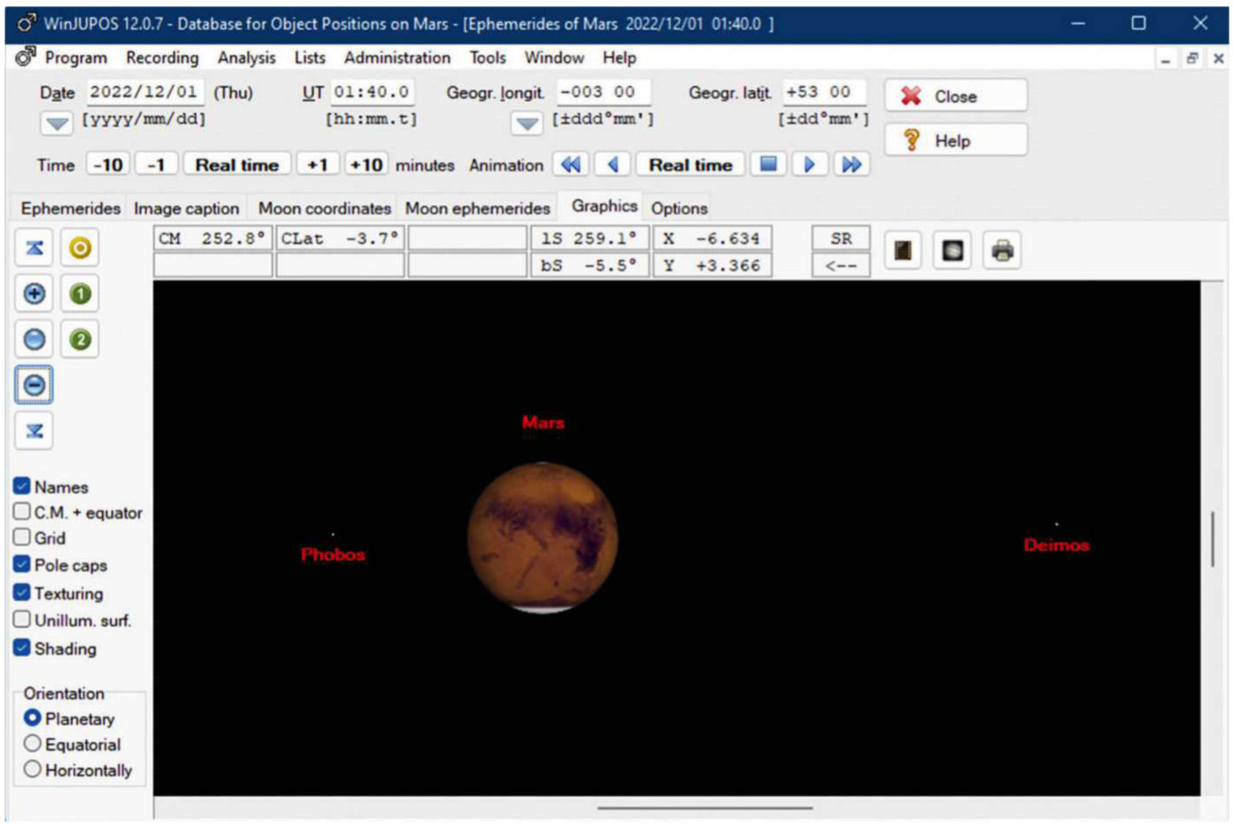
The best time to catch either moon is around east or west elongation

Phobos and Deimos are hard to see and challenging to image, but cameras stand a better chance of recording them. It is generally recommended that attempts are made when Mars is 20 or more arcseconds across through the eyepiece. At opposition on 8 December, Mars will appear 17 arcseconds across, which is less than ideal, but its higher altitude will play a positive part too.

In order to image the moons, you'll need a planetary imaging setup that is capable of recording Mars as a disc. The best time to catch either moon is around elongation, their point of greatest distance, either east or west, from the planet. As they orbit Mars rapidly – Phobos every 7.7h hours, Deimos every 30.3 hours – the recommended strategy is to use a program such as WinJupos (freeware that you can download from **jupos.org/gh/download.htm**) to plan your observation attempts.

As the moons are fairly dim, Phobos being mag. +14.9 and Deimos +16.0, exposures of several seconds or tens of seconds may be required to record them, depending on your setup. If conditions are moist, light scatter on telescope optics or from the atmosphere can enlarge an over-exposed image of Mars to the point where it expands to cover and hide the moons. The best strategy here is to bracket your exposures and record your settings. When you end up processing the results, if you're successful and reveal the dim moons, you'll then be able to reuse the successful settings and refine your results next time.

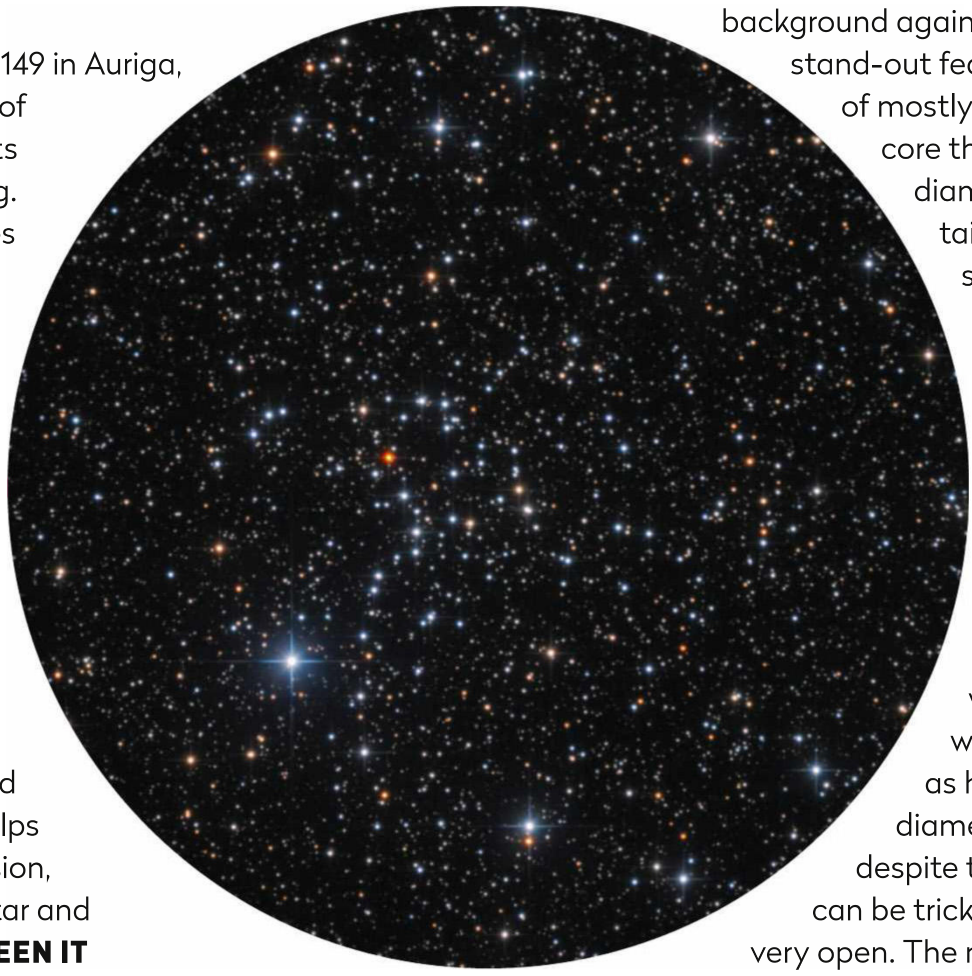
One word of caution if using reflecting telescopes or any instrument that has front mirror supports: diffraction spikes will do a good job of obscuring the moons if the spikes are orientated to lie where the Moons appear.



▲ **A program such as WinJupos will help you pinpoint the locations of the two moons**

DEEP-SKY TOUR

This month we seek out the celestial highlights in Auriga and Perseus



▲ **Diamond-shaped open cluster NGC 1664 with its 'tail' of stars earns its nickname, the Kite Cluster**

MARKUS BLAUENSTEINER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 IC 2149

Our first target is IC 2149 in Auriga, 1.3° north-northwest of Menkalinan (Beta (β) Aurigae), its declination being similar to mag. +4.3 Pi (π) Aurigae, 39 arcminutes to the east. Centre on Pi and drift west by 39 arcminutes to bring IC 2149 into view. IC 2149 is a mag. +10.6 blue-hued planetary nebula that, given its 12-arcsecond diameter, is easily mistaken for a star at low power. Magnifications above 120x show a slightly elongated shape. Its mag. +11.3 central star dominates the view when viewed directly, but with averted vision its elongated nebula appears. An OIII filter helps reveal the nebula with direct vision, radically dimming the central star and keeping the nebula bright. ☐ **SEEN IT**

2 NGC 1857

Next up, an open cluster within the misshapen pentagon of Auriga, 9.2° southwest of Menkalinan and 0.8° south and a fraction east of mag. +4.7 Lambda (λ) Aurigae. NGC 1857 is an interesting cluster dominated by bright orange HD 34545, a mag. +7.4 foreground star 1,500 lightyears away. By contrast NGC 1857 is 18,700 lightyears distant. The cluster can be tricky and a magnification of 100x or more is recommended. A 150mm scope shows about 25 members. A 250mm instrument reveals around 40 stars in an area approximately 10 arcminutes across. A number of 'star-chains' are visible, more prevalent in the south to southwest part of the cluster. ☐ **SEEN IT**

3 NGC 1664

Open cluster NGC 1664 is outside of the Auriga 'pentagon', lying 7° northwest of NGC 1857. An easier way to locate it is to first identify 3rd-magnitude Almaaz (Epsilon (ε) Aurigae) and drift 1.9° west of this star. NGC 1664 is a lovely cluster showing over 30 stars through a 150mm instrument, a number that doubles through a 250mm scope. With a magnitude of +7.2 and a diameter around 18 arcminutes, it's rewarding despite the rich stellar background against which it's located. Its stand-out feature is an extensive asterism of mostly 10th-magnitude stars at its core that resembles a kite: a small diamond panel and long, dangling tail. For this reason NGC 1664 is sometimes referred to as the Kite Cluster. ☐ **SEEN IT**

4 NGC 1582

We can use the equatorial drift trick to locate our next target, another open cluster, NGC 1852, 3.5° due west of NGC 1664. In this position we've left Auriga and are now within Perseus. NGC 1852 is listed as having a magnitude of +7.0 and diameter of 37 arcminutes, but despite these impressive statistics it can be tricky to locate, being sparse and very open. The most obvious features are two loose star arcs of similar lengths that appear to contain several dark, almost starless regions. Due to its sprawling nature, we recommend using a relatively low power here, say 30x or 40x. Go much higher and you'll probably 'see through' the cluster. ☐ **SEEN IT**

5 NGC 1513

This mag. +8.4, 10-arcminute cluster sits 6.8° north-northwest of NGC 1582 within a hooked region of Perseus formed by Delta (δ), 48, Mu (μ), b and Lambda (λ) Persei, all naked-eye stars. Perseus has a curious shape, a bit like a lower-case Pi (π) with extended arms. The hook forms the eastern arm and represents the Greek hero's knee. A hazy patch through smaller instruments, with a 150mm scope around 10 stars are revealed to the south of mag. +9.5 TYC 336-0044-1. With a 300mm scope the count goes up to 30 stars. Look out for the dark teardrop region lined by dim stars immediately south of TYC 336-0044-1. ☐ **SEEN IT**

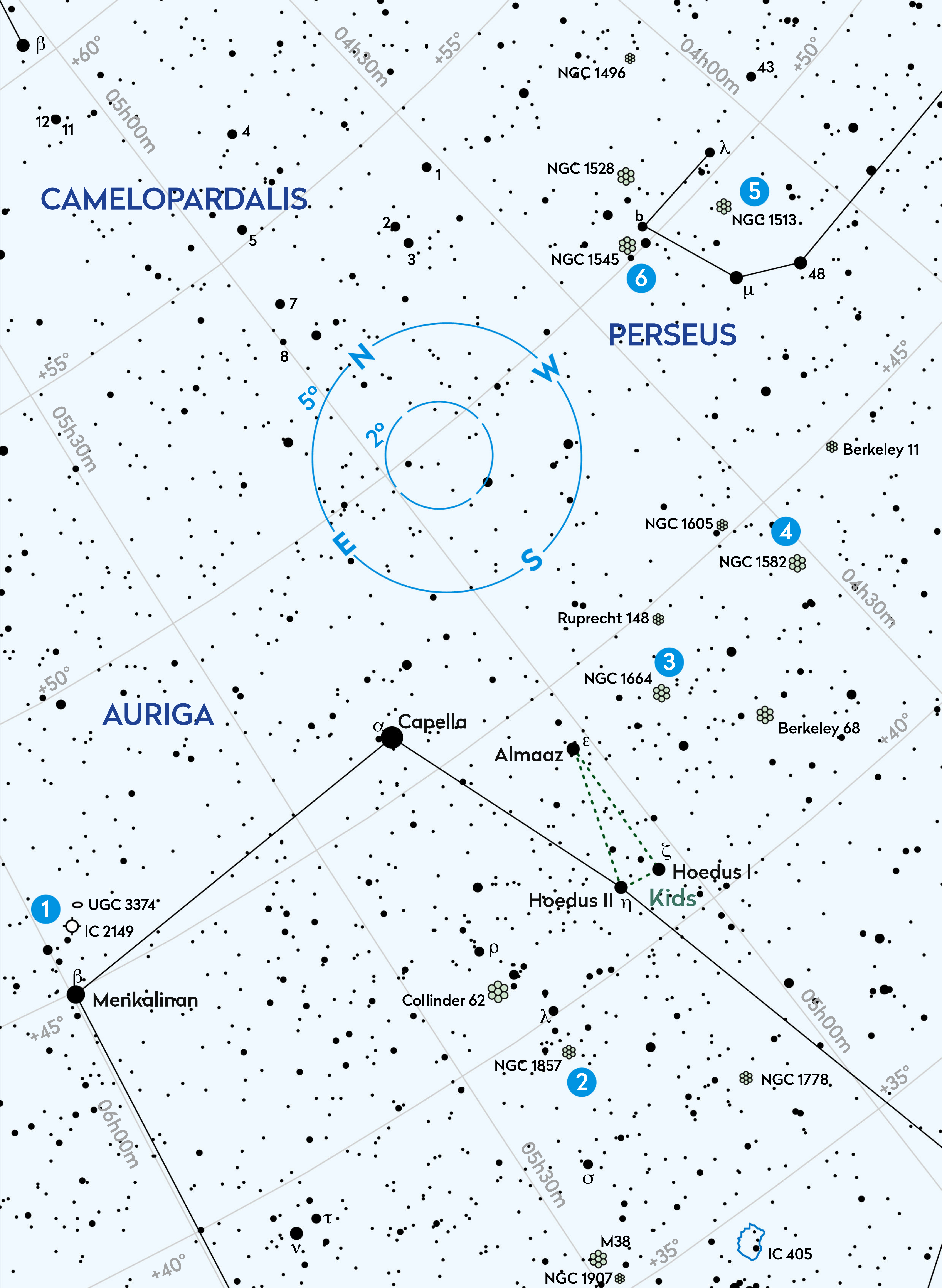
6 NGC 1545

Our final target is another open cluster, NGC 1545. Mag. +6.2 and 12 arcminutes across, it lies 1.9° east-northeast of NGC 1513, 26 arcminutes due east of mag. +4.6 b Persei. b Persei is an interesting star in its own right, a spectroscopic triple, 320 lightyears from Earth. The companions to the A-type giant primary have orbital periods of 1.53 days and 702 days. The three main stars at the core of NGC 1545 give the distinct appearance of a southwest-pointing arrowhead. A 250mm scope reveals a loose collection of around 40–50 stars scattered across a 0.5° circle. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

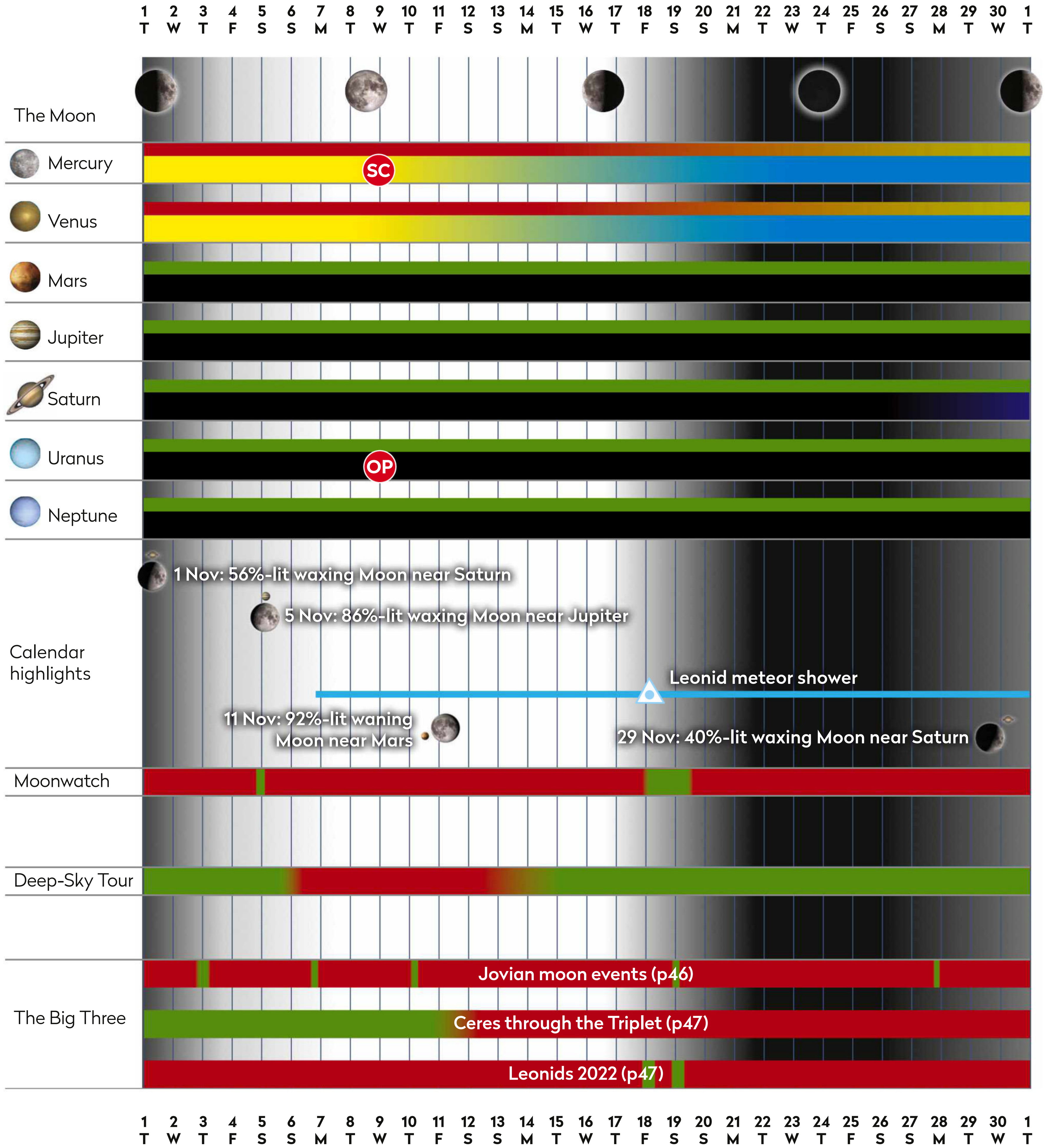
More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.



CAMELOPARDALIS
PERSEUS
AURIGA
NGC 1496
NGC 1528
NGC 1513
NGC 1545
Berkeley 11
NGC 1605
NGC 1582
Ruprecht 148
NGC 1664
Berkeley 68
Capella
Almaaz
Hoedus I
Hoedus II
Kids
UGC 3374
IC 2149
Menkalinan
Collinder 62
NGC 1857
NGC 1778
M38
NGC 1907
IC 405
N
W
S
E
5°
2°
1
2
3
4
5
6
04h00m
04h30m
05h00m
05h30m
06h00m
+35°
+40°
+45°
+50°
+55°
+60°

AT A GLANCE How the Sky Guide events will appear in November



KEY

Observability: Optimal, Poor

Best viewed: Morning twilight, Daytime, Evening twilight, Night

Sky brightness during lunar phases: Dark (first quarter), Light (full Moon), Dark (last quarter), Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

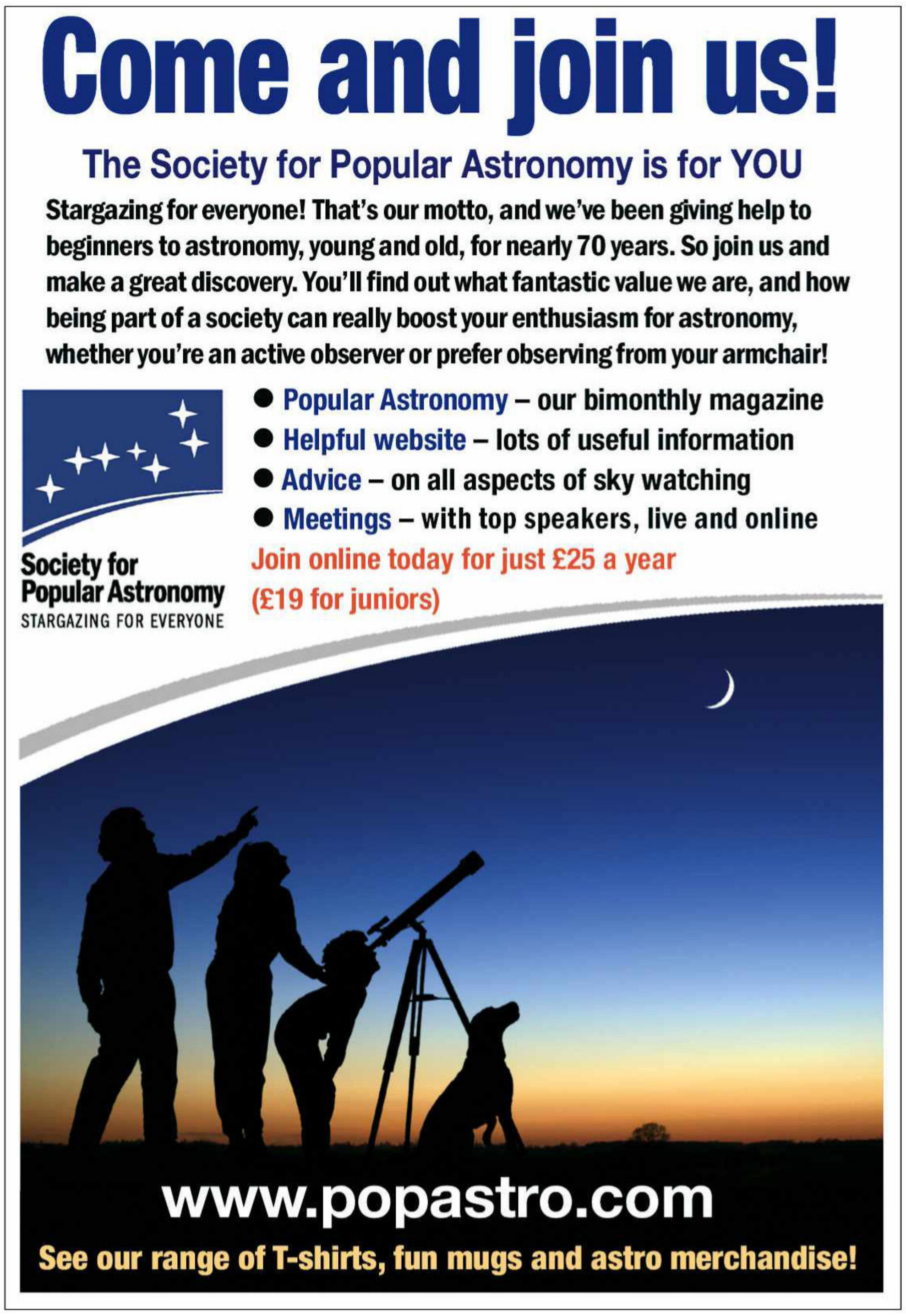
Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE



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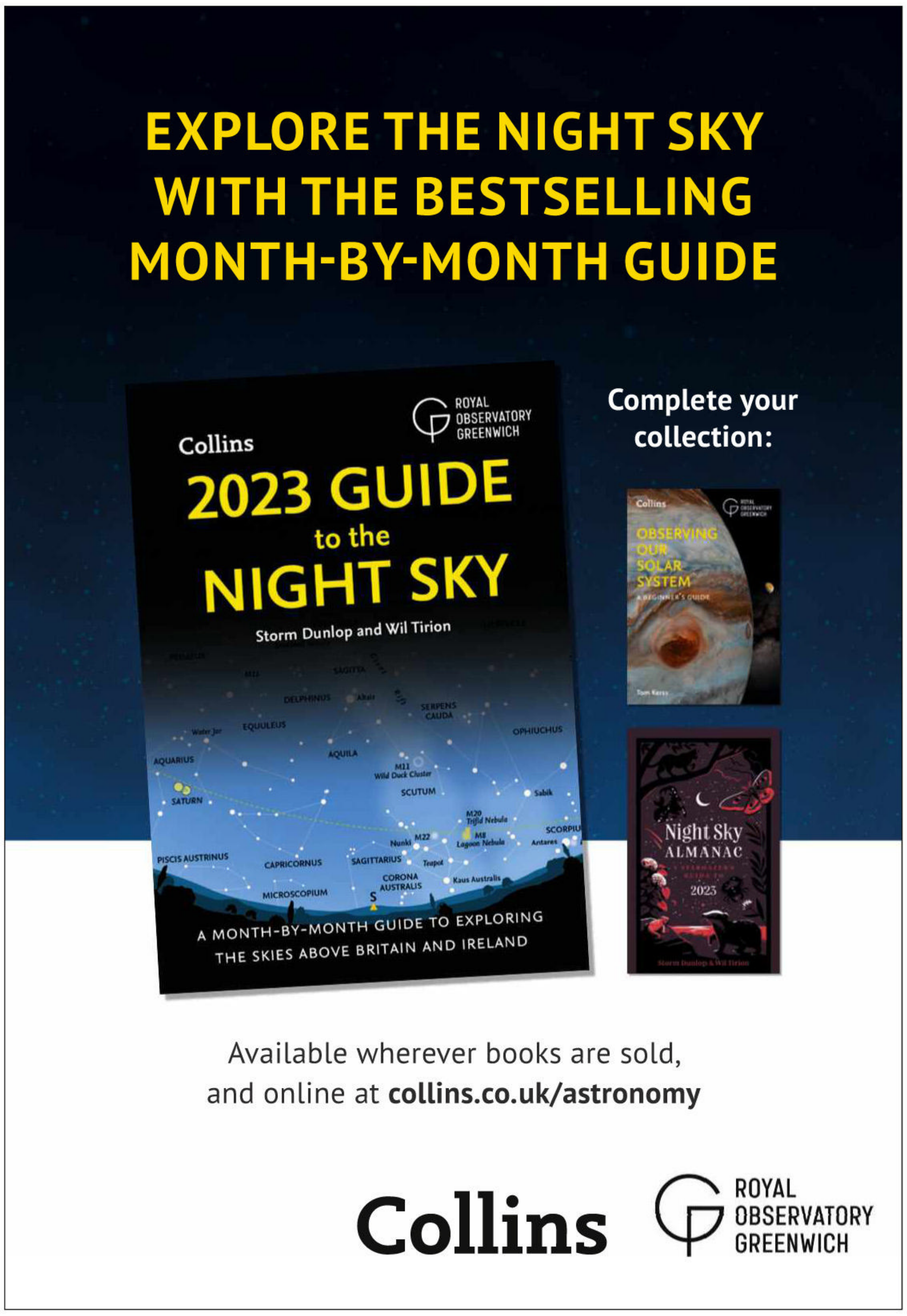

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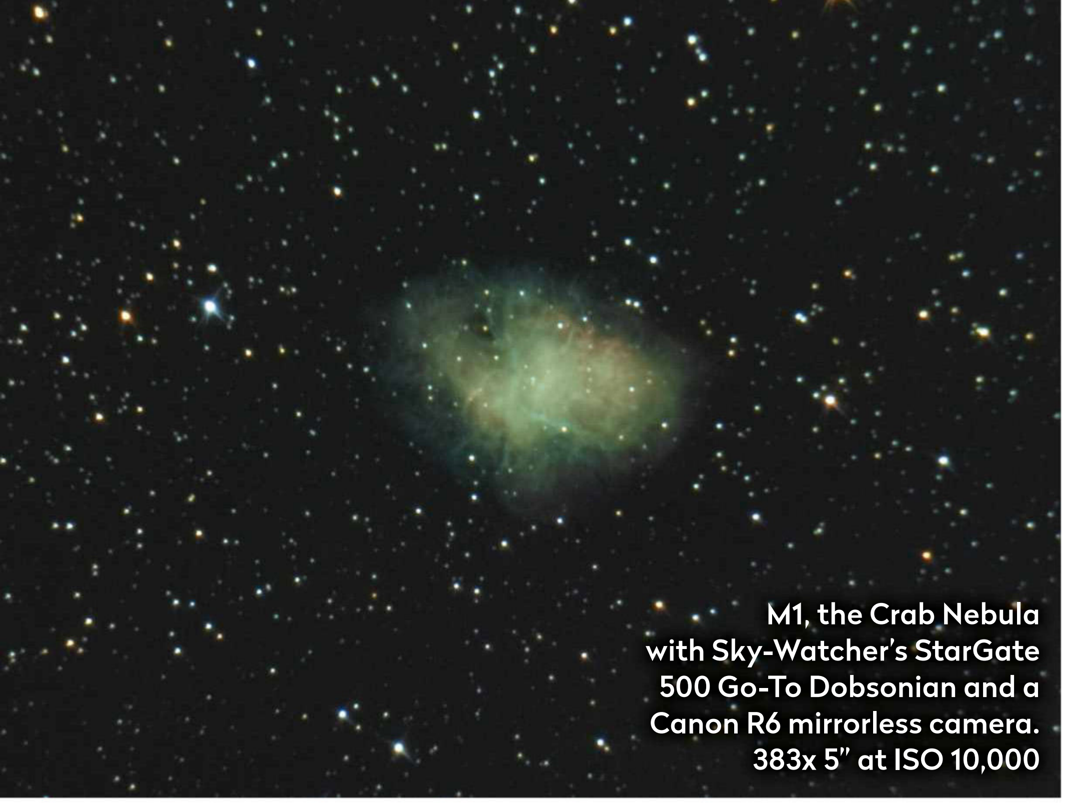
Imaging the deep sky with an ALTAZ PLATFORM

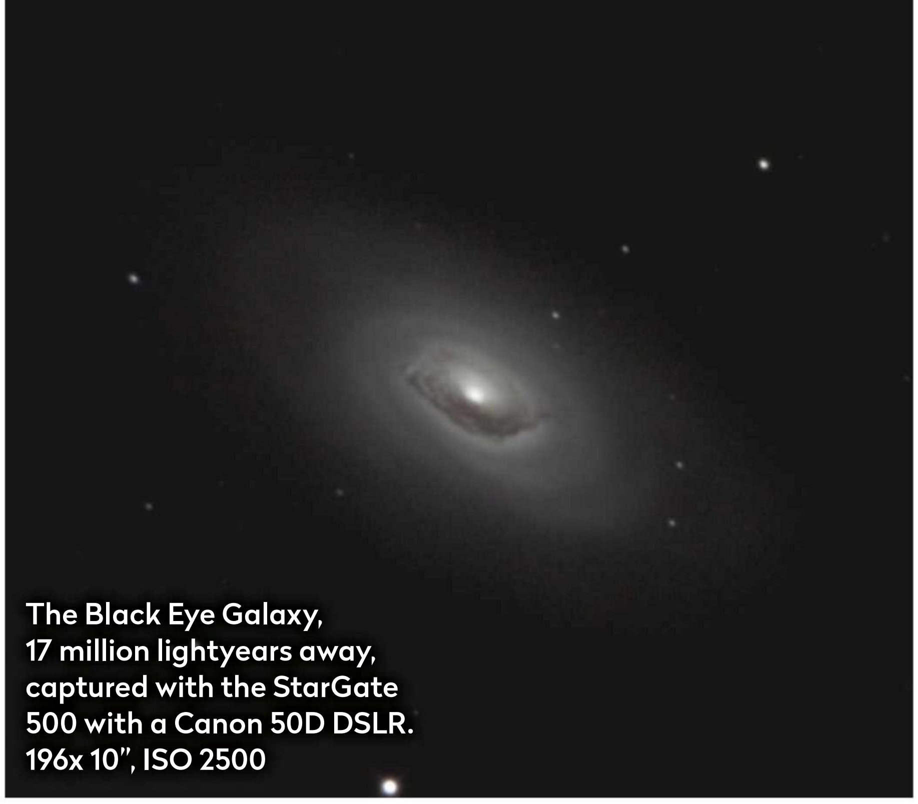
Deep-sky photography is no longer just for equatorial mounts, says **Paul Money**. The latest cameras and processing software are changing the game

Advances in camera and processing software are changing what's possible with Go-To altazimuth setups

Capturing the splendours of the night sky is one of the most rewarding aspects of astronomy, and it's available to anyone with a camera or smartphone coupled to a telescope. However, to achieve the highly detailed photos of deep-sky targets you'll regularly see submitted to our Gallery, the mount of choice is invariably an equatorial. But here we're going to show what can be achieved with a Go-To altazimuth mount, more normally used for imaging the Solar System and our Moon. The results may surprise you! ▸



M1, the Crab Nebula with Sky-Watcher's StarGate 500 Go-To Dobsonian and a Canon R6 mirrorless camera. 383x 5" at ISO 10,000



The Black Eye Galaxy, 17 million lightyears away, captured with the StarGate 500 with a Canon 50D DSLR. 196x 10", ISO 2500

"The good news is that several factors in the last few years have helped Go-To altaz systems overcome their limitations when it comes to imaging the deep sky"

Traditionally, capturing deep-sky objects like nebulae and galaxies requires long-exposure images, and to facilitate this an equatorial mount is the ideal choice. Equatorial mounts have one axis aligned with the celestial pole, which allows you to follow a target smoothly across the sky in an arc, keeping the object in the same orientation in either the eyepiece or image frame. A mount that's accurately polar-aligned lets you take exposures several minutes' long or, by adding a guidescope and camera, even longer. These images are often taken at relatively low ISO values for a DSLR (or a low gain setting for a dedicated astro camera) and have a lot of data in them to provide a good final stacked image.

Solving the rotation problem

It's usually understood that a Go-To altaz setup can't be used for deep-sky astrophotography, as you can't get the minutes-long exposures with such systems. The computer that controls them tracks the selected target across the sky and keeps it reasonably centred, but exposures need to be kept short, usually under a minute, because of an effect known as field rotation.

This effect is down to the nature of the mount. Altaz systems don't have an axis that's aligned with the celestial pole, but instead work in the same way as a standard photographic tripod set level with the horizon. So as the telescope tracks a target, the field of view of the eyepiece or camera remains oriented with the horizon regardless of where it is in the sky, and the view slowly rotates in the frame. Thus, very long exposures will show the stars in slight curves instead of nice pinpricks. No amount of postprocessing wizardry will help with this.

The maximum duration of Go-To altaz exposures also varies with the location of the target in the sky. Aim towards the polar regions and you can expose for longer; aim towards the celestial equator and you have to cut down the exposure to avoid any trailing. You have to contend with the same effect when you take untracked photos of the constellations.

But the good news for those who own them is that several factors in the last few years have helped Go-To altaz systems overcome their limitations when it comes to imaging the deep sky and getting acceptable results. Crucially, the software used for stacking and derotating images has taken great strides, so that suitable data can be aligned and stacked. DeepSkyStacker is a free program that will do this, while paid-for software such as PixInsight, Astro Pixel Processor and MaxIm DL do it too, and have a vast array of other image processing abilities that can be applied.

That takes care of the field rotation problem, but deep-sky targets are often faint and require long exposures to capture well. Until recently this was one of the main factors ruling out a Go-To altaz setup. Happily, these days it is less of an issue. Modern DSLR cameras now have much higher ISO settings – the sensitivity of the camera sensor to detecting the

▲ The famous Pillars of Creation, M16, using the same motorised Dobsonian paired with Altair GPCAM 290c, 158x 5"

PAUL MONEY X 3, DEEP SKY STACKER

Software to straighten the stars

Programs that will derotate and stack your captured data

◄ DeepSkyStacker aligns your frames to deal with star trailing

FREEWARE

DeepSkyStacker

deepskystacker.free.fr/english/index.html

Stacking and derotating software with basic image processing.

Siril

siril.org

Image calibration, stacking, processing and other capabilities.

Sequator

sites.google.com/view/sequator

Basic Windows-only image stacking and some postprocessing features.

PAID-FOR

PixInsight

pixinsight.com

An advanced and complex image processing program that can derotate, stack and process images.

Astro Pixel Processor

www.astropixelprocessor.com

Feature-rich software for derotating, stacking and processing images.

MaxIm DL

diffractionlimited.com/product/maxim-dl

A sophisticated image processing program that comes in a variety of versions.

Astroart 8

www.msb-astroart.com

The latest version of this all-inclusive image capture and processing software package.

photons striking it – and you can now go as high as ISO 3,200, 6,400 or 10,000 (and even, under very dark skies, up to 20,000!). This is compared with the much lower ISO values found on past models, typically in the region of 800 or 1,600, when you had to take long exposures to capture the faint light of deep-sky objects. Today's higher ISO values make it possible to cut down the exposure time to something that still gives you worthwhile raw image data suitable for stacking, but doesn't introduce any star trailing.

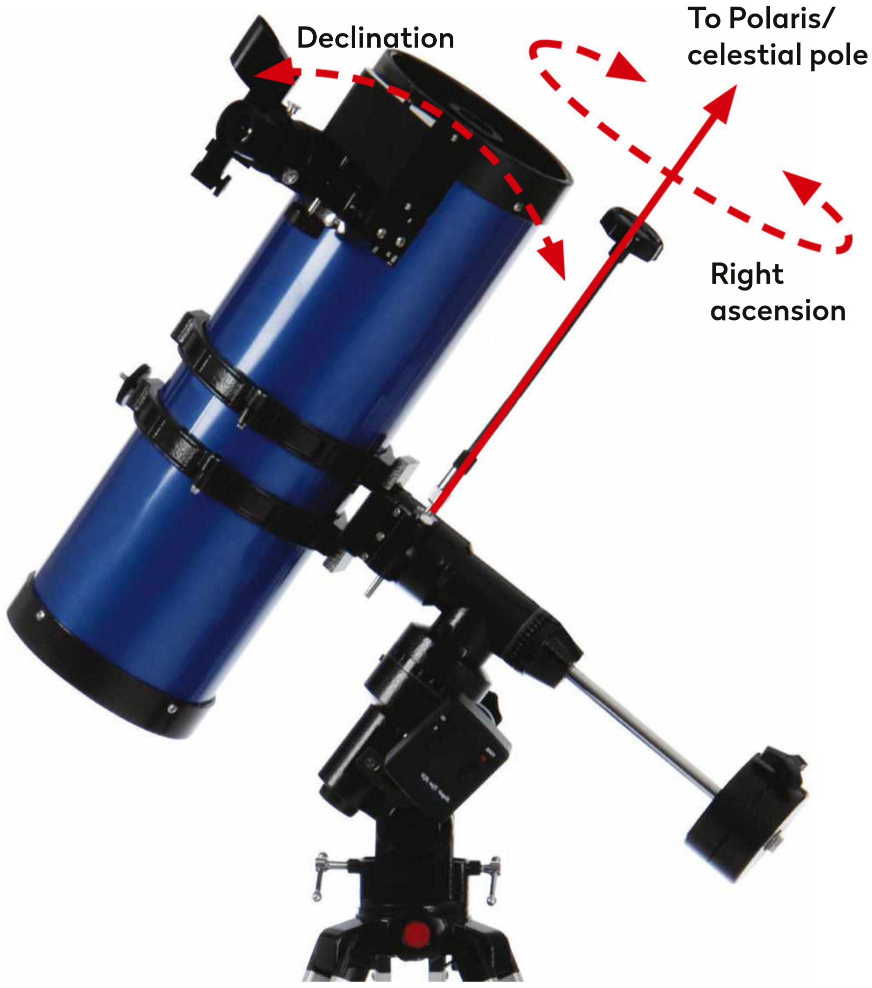
Stacking up the data

While ISO numbers apply to the DSLRs and mirrorless cameras often used by those starting out in astrophotography, astro imagers also use dedicated cameras where the sensitivity is referred to as 'gain'. These dedicated astro cameras – from the likes of Atik, ZWO and Altair Astro, among others – have also seen a dramatic increase in sensor sensitivity. The upshot of higher ISO and gain is that you can capture data-rich images of between one second, five seconds and 30 seconds' exposure without having to worry about the effects of field rotation.

Of course, in the world of deep-sky imaging, even a 30-second exposure won't capture much of a target's faint data. You need to take many more images than if you were imaging with a guided setup on an equatorial mount that could expose for longer. There ►

► Altaz mounts are popular and easy to use but won't keep celestial targets stationary in the view frame, unlike equatorial mounts which are polar-aligned to stop the field of view rotating

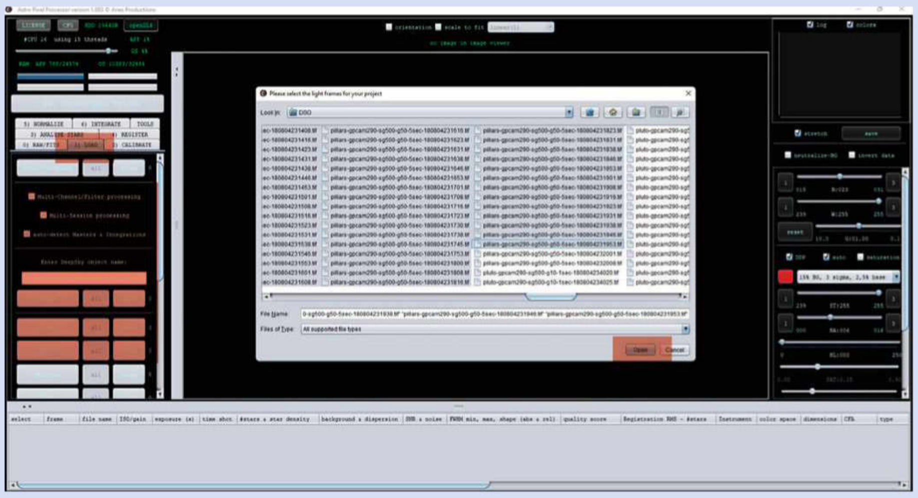
Altaz mount



Equatorial mount

Stacking and derotating images with Astro Pixel Processor

Follow our guide to using APP to iron out the imperfections in your Go-To altaz image captures

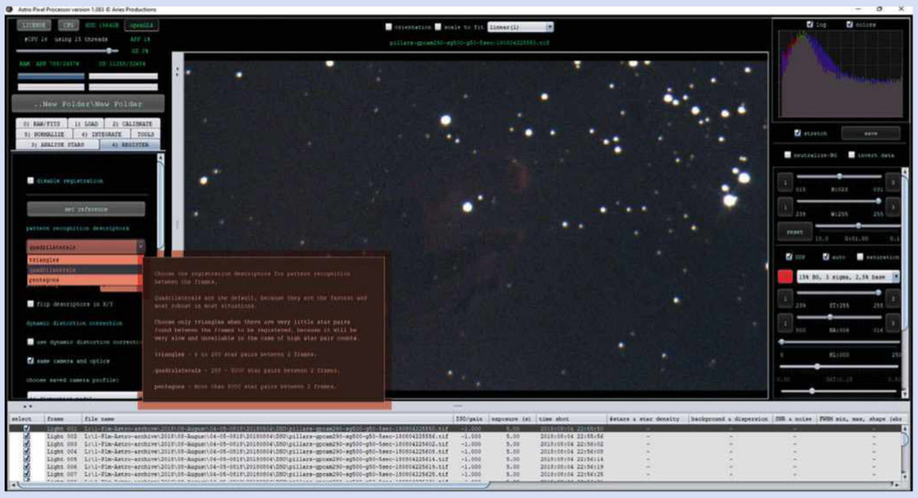


STEP 1

Open Astro Pixel Processor. Select the tab marked 1) Load. Navigate to your working folder that contains all of your image files. Select the light frames of your target and click 'Open' to load them. If you have dark and flat frames, select and add those to the selection too.

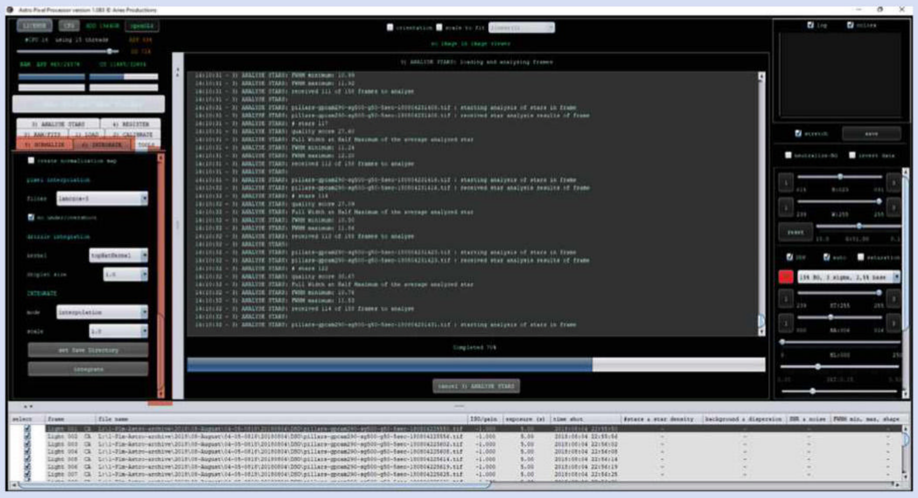
STEP 2

Give your image an appropriate name for when the processing run has finished (you can change it at the end if you wish). Then check tab 2) Calibrate and tab 3) Analyse stars. These can usually be left at their default values unless you feel inquisitive and want to test out some adjustments.



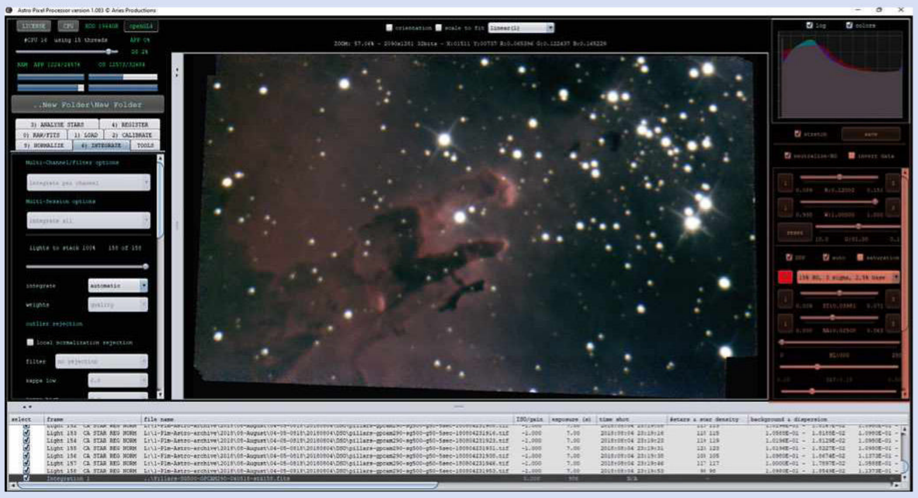
STEP 3

Select tab 4) Register to bring up its window. 'Quadrilaterals' is the default setting for the pattern recognition descriptors, but if you have 250 stars or less choose 'Triangles'. The software has a useful pop-up window with lots of information that appears and helps to guide you throughout.



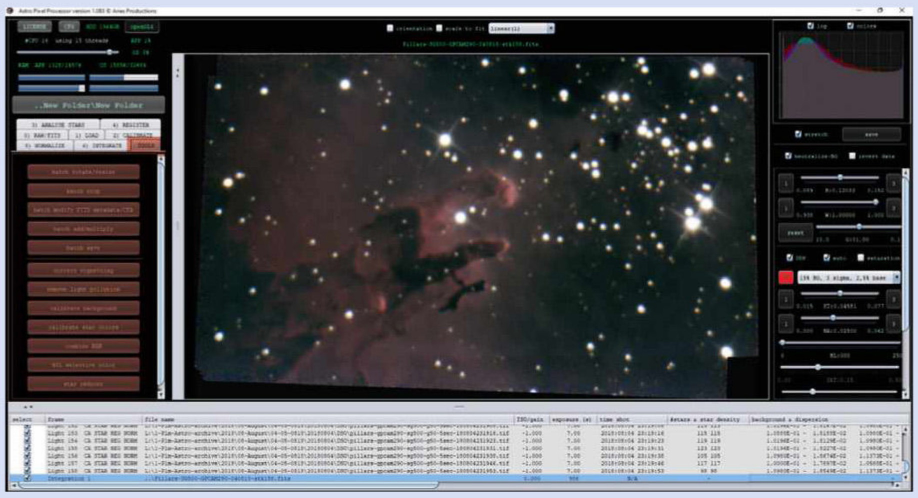
STEP 4

Open tab 5) Normalise and ensure 'Neutralise background' is unticked. Click on tab 6) Integrate. The default settings work well and there are plenty of options for experienced imagers to play with. Scroll to the bottom and click 'Integrate'. This then runs through all the previous tabs and processes your image.



STEP 5

A short beep announces that the integration is complete and the above screen will appear with a stacked, aligned and processed image displayed. On the right, select 'Neutralise background' and there are a range of options to adjust the image; the default settings often give good results.



STEP 6

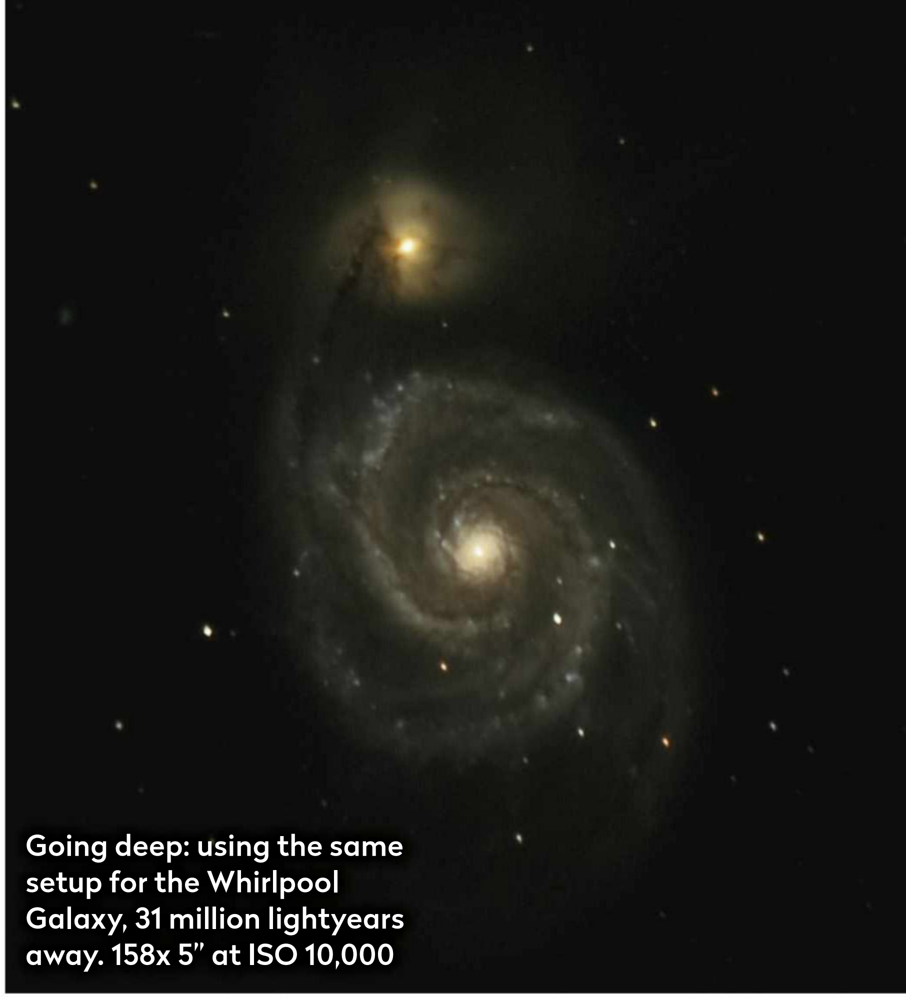
A final set of tools is provided to process the image further; those that remove light pollution, calibrate background and calibrate star colours are particularly useful, and experienced imagers have plenty of options to experiment with. Once done, save your image ready to import into your favourite photo-editing program.

ALL PICTURES: PAUL MONEY

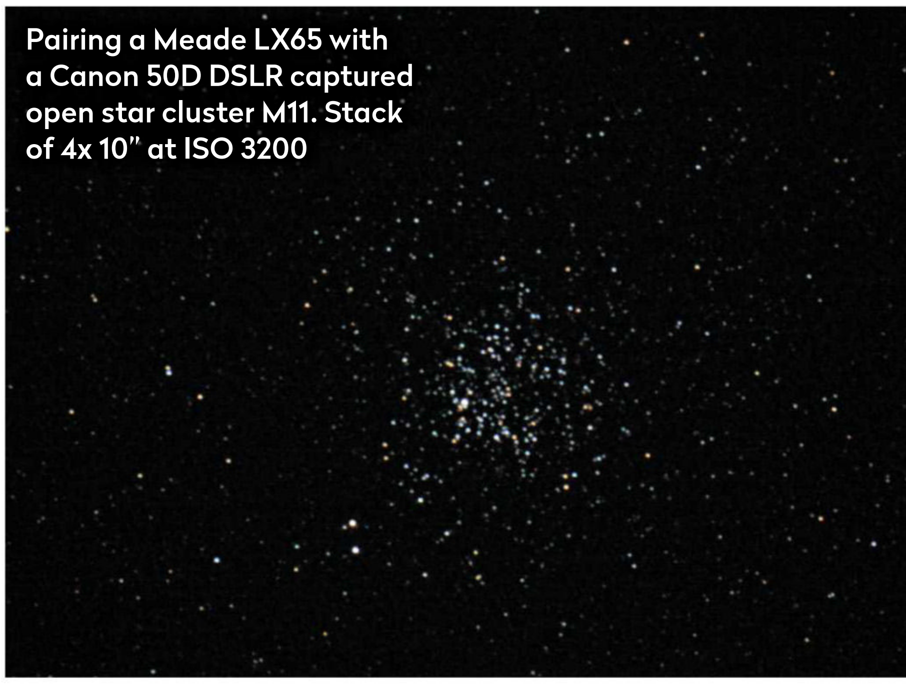
▲ A Canon R6 camera with a StarGate 500 captured this image of the Running Man Nebula. Stack of 376 5-second exposures at ISO 20,000

▸ are a couple of considerations when it comes to processing these images. Firstly, all of your captures taken together may be many megabytes in size. It's advisable to have a fast laptop or computer system capable of capturing and downloading them all, and then stacking them together to enhance the target. Note that when capturing your data, you should still capture flat and dark frames, which further add to the processing your computer has to perform.

A second consideration is that all this processing requires a computer with a relatively high specification. Yours may not take long to process a small number of images, but when you're taking several hundred images, each of 10MB, 20MB or even 60MB, your system's processor, memory and graphics capability is really put to the test! If you have an average spec computer, you should prepare to be patient – but the good news is that the results are often worth the wait.



Going deep: using the same setup for the Whirlpool Galaxy, 31 million lightyears away. 158x 5" at ISO 10,000



Pairing a Meade LX65 with a Canon 50D DSLR captured open star cluster M11. Stack of 4x 10" at ISO 3200

A new breed of telescope

There is an old adage in astronomy circles: bigger is better. When it comes to the best aperture telescope for a Go-To altaz setup, this is still true. However, these days it's not such a crucial issue, thanks again to the increase in ISO and gain sensitivity of modern cameras. This factor allows relatively small- and medium-aperture systems to obtain good results. Recent successful examples include the Sky-Watcher Star Discovery P150i Wi-Fi telescope, the Celestron Astro Fi 6 Schmidt-Cassegrain telescope and the Meade LX65 Series 8-inch ACF telescope.

These performed well during our reviews (which you can find on our website) with short exposures of 1–10 seconds on targets such as the Ring Nebula, M57, the Double Cluster, NGC 869 and NGC 884, globular cluster M3, and M45, the Pleiades open cluster. In recent years we have also seen high-quality altaz tracking mounts such as the TTS-160 Panther come on the market, which, when coupled with a field rotator, can produce stunning results too.

Stepping up the scale to the larger 'light buckets', we have achieved good results with systems like Sky-Watcher's StarGate 500 Go-To Dobsonian, imaging such targets as M1, the Crab Nebula, the double-shelled planetary nebula NGC 2392, M64, the Black Eye Galaxy and even the famed Pillars of Creation in M16, the Eagle Nebula. But there is a caveat here. Large aperture, coupled with very high ISO or gain settings, can mean you surpass the sky brightness levels for the amount of light pollution in your location, and wash detail out. So, although some DSLR and mirrorless cameras can be set to ISO values of more than 100,000, you will always have to experiment with your settings accordingly, unless of course you are imaging under an exceptionally dark sky.

Another relevant development is the advent of fully automated altaz smart systems able to take, process and display images live, on the fly, via your smartphone or tablet. These include the Stellina, Vespera and Hyperia systems from Vaonis, and the eVscope 2 and eQuinox smart telescopes from UniStellar. It's a trend that is set to continue, giving us perhaps a glimpse of the telescopes of the future.

Although altaz systems may not seem like obvious deep-sky imaging setups, with modern advances in the computer control of these mounts, coupled with today's highly sensitive cameras and latest processing software, you can produce images of galaxies, nebulae and clusters that are both pleasing and rewarding to capture. Just as many of the world's professional observatories use computerised altaz mounts, perhaps Go-To altaz setups will catch on for amateur astro imaging. Only time will tell.

Paul Money is an astronomy writer, broadcaster and the reviews editor for *BBC Sky at Night Magazine*

A farewell to airborne astronomy

Niamh Shaw takes a trip on one of the final flights of the plane carrying the SOFIA observatory

▲ SOFIA, a powerful 19-tonne infrared telescope mounted on a specially modified Boeing 747SP, was retired from duty in September 2022

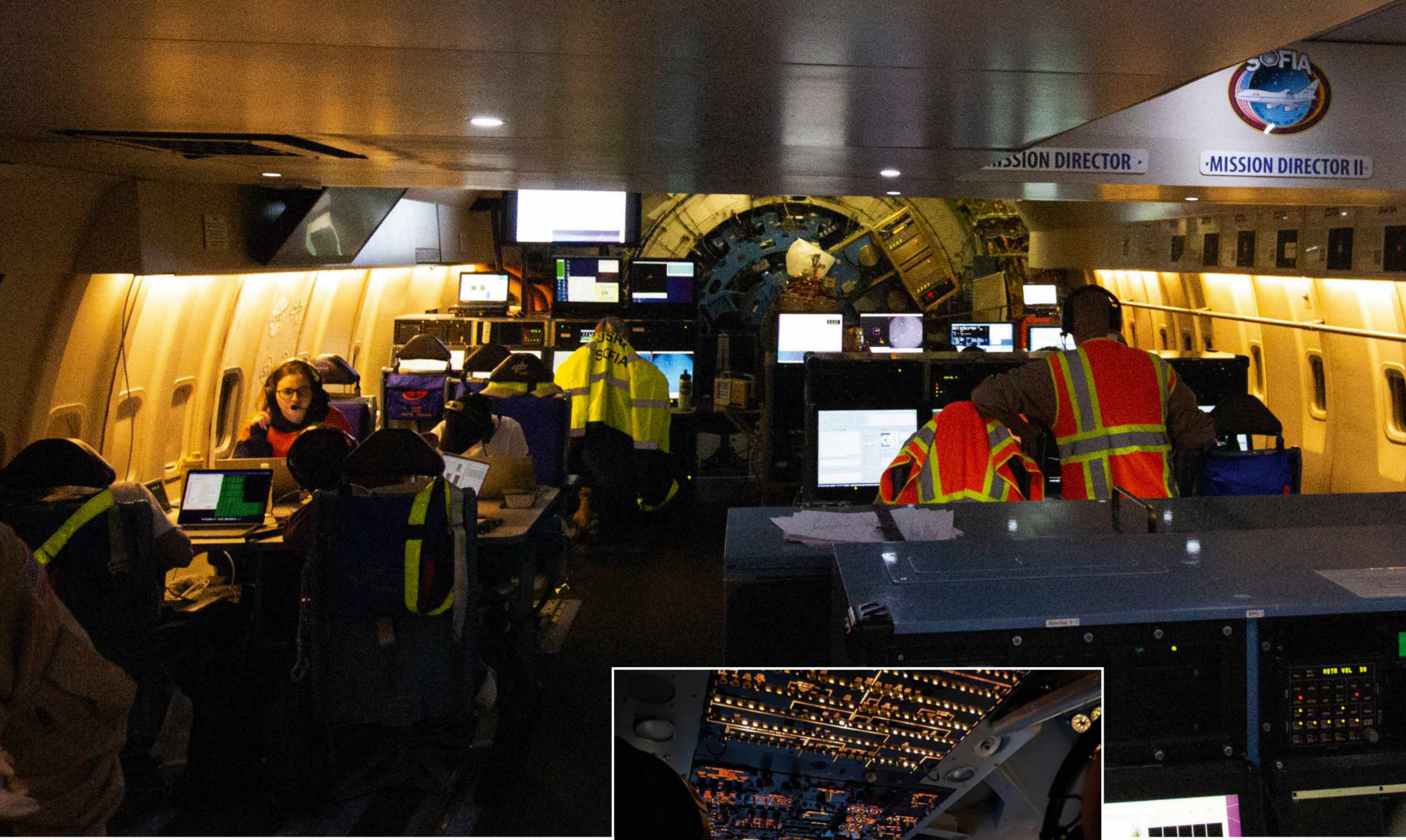
The time is 5:30pm on 8 September 2022 and I'm in the mission briefing room at NASA's Armstrong Flight Research Center in Palmdale, California. I'm about to board a very special aircraft: the Boeing 747 SOFIA aeroplane, carrying a 2.5-metre infrared telescope operated by NASA and DLR, Germany's space agency. It is one of SOFIA's last flights; by the time you read this the programme will have ended.

Inside, the cabin is buzzing with activity. It's extremely loud, so headsets are essential for communication. I tune in to the flight deck comms channel and hear pilots Spike and Bill, and flight engineer Rick. Spike's the joker and the three enjoy a few laughs together as they wait for clearance. It's Spike and Bill's final SOFIA flight. They've been flying together for 24 years, having begun their professional relationship in the US Air Force.

The Stratospheric Observatory for Infrared Astronomy (SOFIA) was a long time coming, with development of the project beginning back in 1996. SOFIA was originally a commercial Boeing 747SP acquired by Pan Am airlines in 1977, and the aircraft still carries the name 'Clipper Lindbergh' in honour of aviator Charles Lindbergh. Extensive modifications were made when it was acquired by NASA in 2007, and in 2009 its ▸

▼ Niamh about to take off from the Armstrong Flight Research Centre in California

NASA/JIM ROSS, FLORIAN BEHRENS



▲ The science teams analyse the incoming data from the FORCAST infrared instrument

▸ telescope cavity doors were opened in full flight for the first time. In May 2010, SOFIA completed its first in-flight tracking of astronomical targets – the planet Saturn and the stars Beta Leonis and Beta Orionis – and in July 2013 it made its first deployment to New Zealand for observations of the southern winter skies.

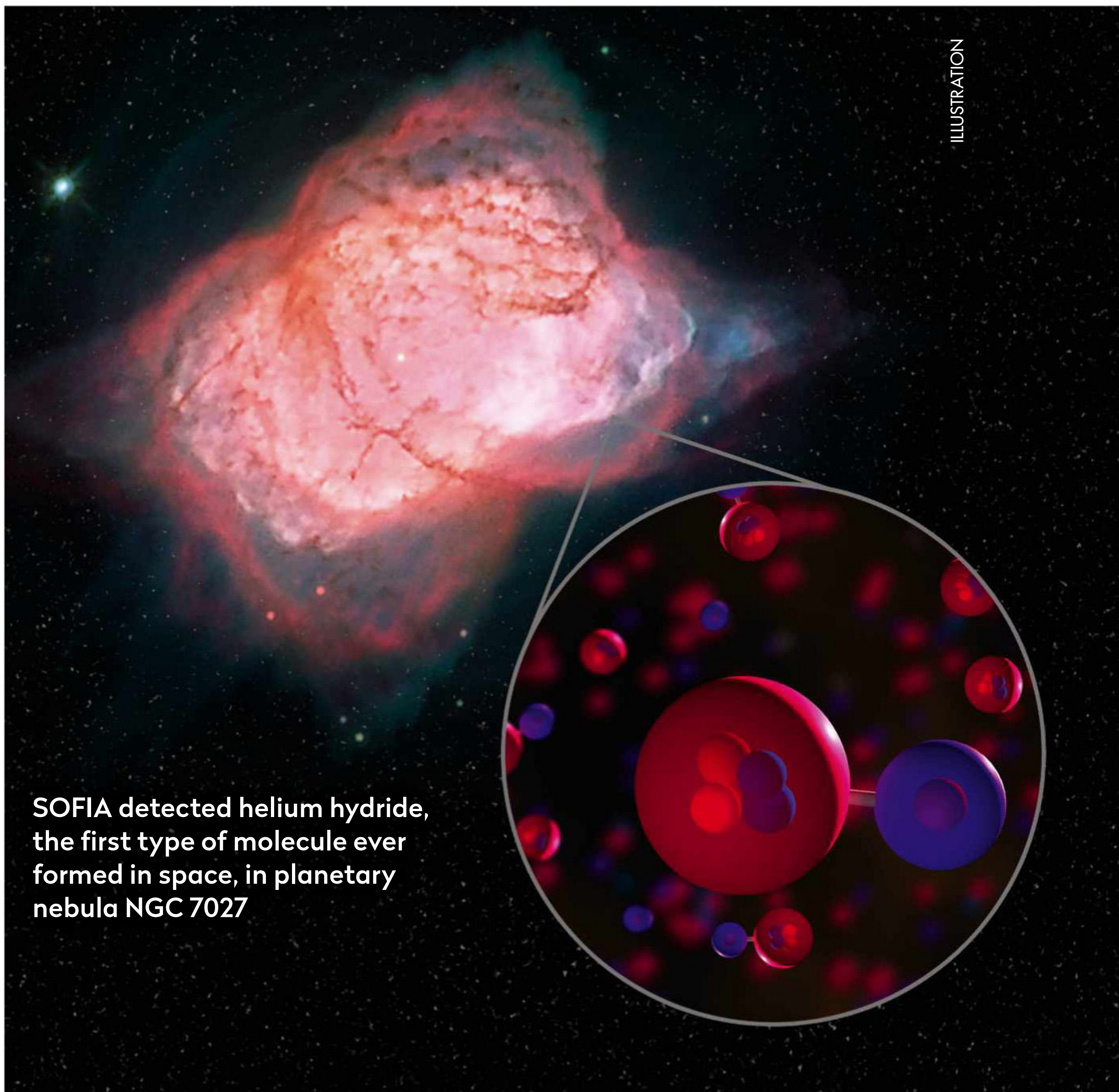
Throughout the programme, SOFIA's 10-hour flights have taken it as high as 45,000 feet, soaring above Earth's distortive atmosphere and giving it an important advantage over ground-based telescopes. From that height, its infrared view penetrated cosmic clouds of dust and gas, enabling astronomers to study the lifecycle of stars, distant nebulae and galaxies and supermassive black holes residing in galactic centres. It also observed closer to home, analysing the planets, comets and asteroids in our own Solar System.

My journey with SOFIA began a few months previous, when I heard that the NASA programme had just one last deployment to New Zealand to complete. I headed to Christchurch in late July 2022 with the intention of joining operations on the ground, working out of the US Antarctic Program building. Unfortunately, severe weather in July had damaged the aircraft, and it wasn't able to finish its Southern Hemisphere deployment. In late August, SOFIA returned to California to carry out the remainder of its mission.

High-flying science

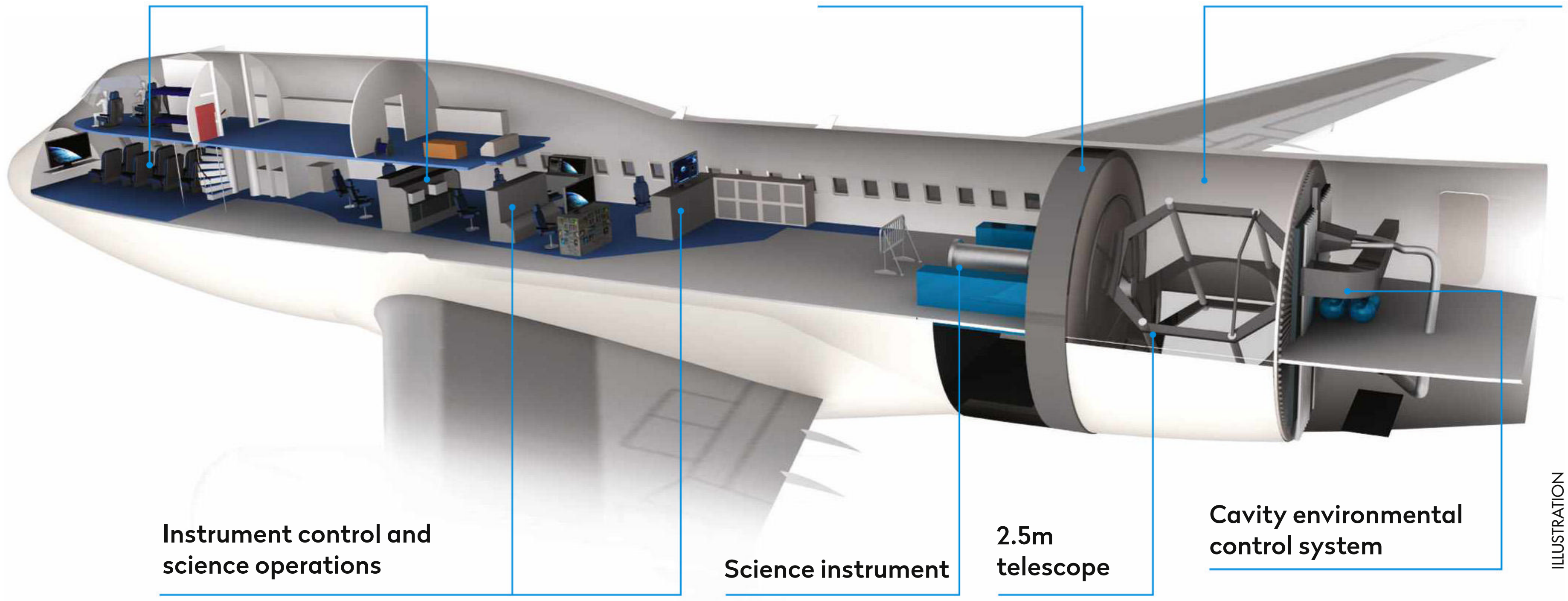
While in New Zealand, I met Margaret Meixner, the director of science operations. "The southern deployment became an essential part of the SOFIA programme," she told me, "because there are objects that can only be seen from the Southern Hemisphere; objects like the Galactic centre, which are incredibly important to observe."

◂ Co-pilot Michael 'Spike' Tellier in the cockpit during his last shift on SOFIA



SOFIA detected helium hydride, the first type of molecule ever formed in space, in planetary nebula NGC 7027

NIAMH SHAW X 3, NASA/ESA/HUBBLE PROCESSING: JUDY SCHMIDT, SOFIA
CUTAWAY ILLUSTRATION BY PAUL WOOTTON, CARLOS DURAN/MPIFR



▲ **The specially modified Boeing interior included banks of computers to manage the data gathered during a flight**

Mike Toberman, NASA's SOFIA project manager, was on every New Zealand deployment. "We started in 2013," he says, "and it was to be a short mission. But when the scientists got off the plane, they were ecstatic and said it was like observing from space. We kept extending the duration of the appointments, from six weeks to two months."

Equipped for success

There were many bodies involved in SOFIA, with the main actors being NASA and DLR. The 2.5-metre onboard telescope was designed and maintained by the German SOFIA Institute in Stuttgart. This vital instrument observed at mid- and far-infrared wavelengths, which enabled astronomers to see regions of the cosmos that would otherwise be invisible, such as hydride molecules, some of the first molecules to form in the Universe.

"One of the science highlights of SOFIA, the biggest, probably most noted to the public, is the discovery of water on the sunlit surface of the Moon," Meixner told me.

"Another highlight has been observing hydrides from our instrument GREAT [see below]. Hydrides possess bright rotational transitions in the far infra-red. Measuring them is critical to understanding and really pinning down the processes of astrochemistry."

SOFIA's scientific achievements would be the envy of any ground-based observatory. It has mapped magnetic fields in objects like the Whirlpool Galaxy ▸

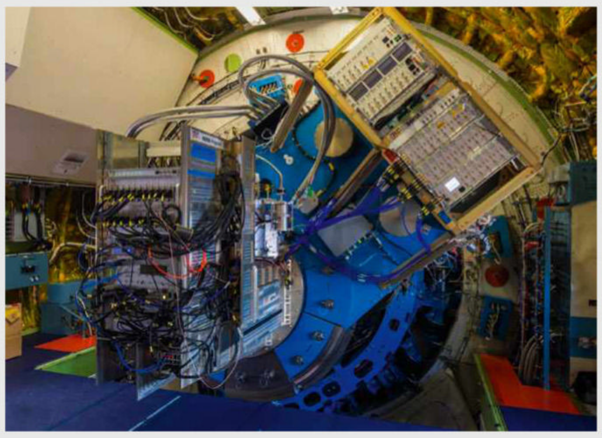
Infrared instruments

How SOFIA's on-board instruments equipped the plane to observe the Universe

SOFIA housed six separate instruments that were swapped out regularly to allow the telescope to collect data at wavelengths ranging from near-, mid- to far-infrared, making it a versatile observatory.

FORCAST (Faint Object InfraRed CAmera for the SOFIA Telescope)
This instrument was in operation on my flight and that evening observed edge-on galaxies, the sunlit side of the Moon and the Galactic mid-plane. It is a dual-channel mid-infrared camera and spectrograph sensitive to the mid-infrared range of 5–40μm. But SOFIA hosted a range of other instruments, depending on what astronomers wanted to observe.

GREAT (German REceiver for Astronomy at Terahertz Frequencies)
A far-infrared high-resolution multi-pixel spectrometer that didn't produce pictures of stars and galaxies, but rather extremely detailed spectra of their atoms and molecules. It was used in the first-ever detection of the helium hydride molecular ion (HeH+) in interstellar space.



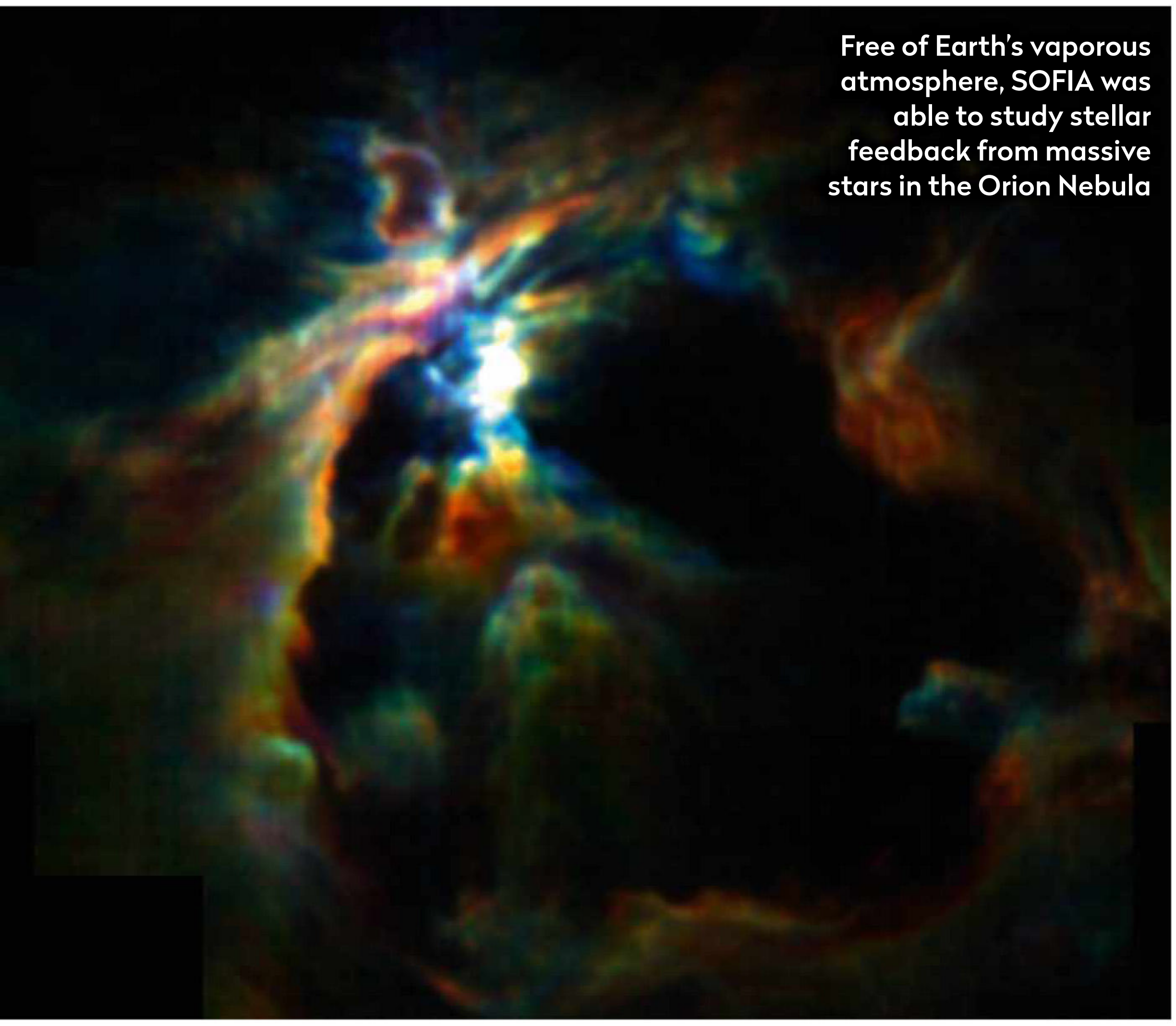
▲ **The GREAT far-infrared spectrometer mounted on SOFIA's 2.5-metre telescope**

HAWC+ (High-resolution Airborne Wideband Camera Plus)
A camera and imaging polarimeter that imaged in far-infrared light and was used for observing the early stages of star and planet formation, as well as producing maps of magnetic fields.

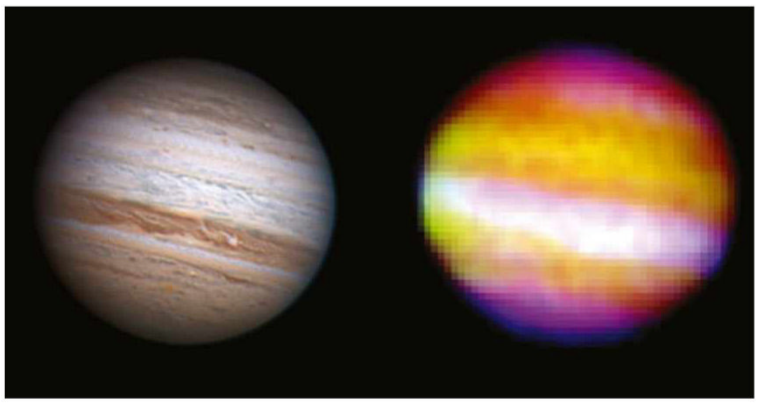
FIFI-LS (Far-Infrared Field-Imaging Line Spectrometer)
A far-infrared spectrometer able to trace the formation of massive stars and peer through cosmic dust to analyse star-forming regions.

FPI (Focal Plane Imager)
A tracking and high-speed imaging camera used as a fast-frame-rate imaging photometer in the 360–1100nm wavelength range.

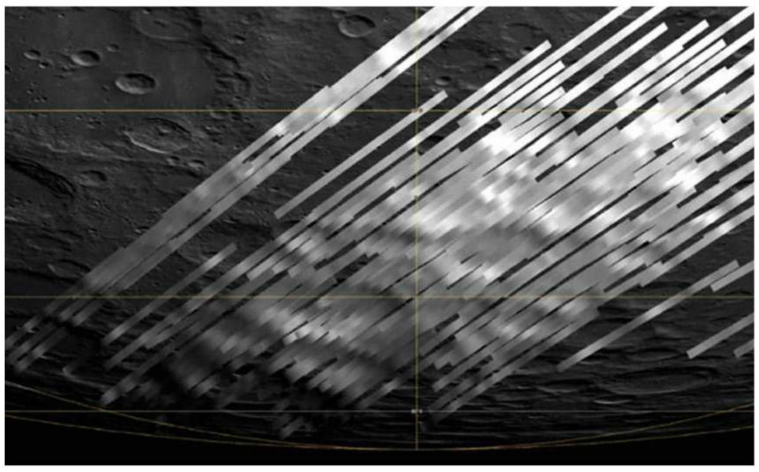
EXES (Echelon-Cross- Echelle Spectrograph)
Used to split light into a spectrum, enabling astronomers to study chemicals like hydrogen, water vapour and methane from molecular clouds, planetary atmospheres and protoplanetary discs.



Free of Earth's vaporous atmosphere, SOFIA was able to study stellar feedback from massive stars in the Orion Nebula



▲ Jupiter imaged with the FORCAST camera at infrared wavelengths that would be impossible from Earth



▲ An abundance map for molecular water at the Moon's Moretus crater, again using FORCAST

▸ and supernova remnant Cassiopeia A. It captured an infrared view of temperature changes on Jupiter and studied the formation of planetary systems around distant stars. It discovered how powerful stellar winds are hindering star formation in the Orion Nebula, revealed that magnetic fields are feeding material into the supermassive black hole in galaxy Cygnus A, and detected evidence of a recent exoplanet collision in a double-star system just 300 lightyears away. In 2011, SOFIA flew 2,900km from its Californian base, over the Pacific Ocean to observe Pluto occulting a distant star, providing information about the pressure, density and temperature of the dwarf planet's atmosphere. That's something ground-based observatories could only dream of.

Up in the air

On board my Palmdale flight, I notice how busy the plane is at each of the console areas as scientists make preparations for the collection of data by the FORCAST instrument, SOFIA's infrared camera and spectrograph. Callie Crowder, who is managing the telescope, prepares for the telescope door opening, the first big event of the night. Over the course of the flight we will observe edge-on galaxies, the sunlit side of the Moon and the galactic mid-plane. It's a relentless schedule focused on maximising observation time.

I join the pilots in the cockpit upstairs and notice the mood is a lot more relaxed here. I ask Spike how he feels to be on his last-ever SOFIA flight. He says it's a privilege to have been a part of the programme, and that the deployments to Christchurch were a particular highlight. "It felt as if the whole of Christchurch knew whenever SOFIA came to town. People were so welcoming. I was very proud of my job when on deployment there."

▲ The Educators and Public Outreach Console displaying live pictures from the telescope as it focuses on the sunlit Moon during Naimh's flight

He's right. In Christchurch, whenever I mentioned the reason behind my visits to any of the locals, they perked up and shared their own SOFIA stories. But this was contrasted with disappointment that the current deployment would be SOFIA's last. In early August 2022, as I left Christchurch on my way to California to catch my SOFIA flight, two officers at passport control took me to one side. I shouldn't have worried, because they had just discovered the purpose of my visit and wanted to speak more about SOFIA. There had been a TV news special the night before, highlighting the mission's cancellation. They asked if there was anything they could do to show support and wanted me to thank NASA and DLR for their visits over the years.

The end of SOFIA was tough news for the science team. NASA's astrophysics division decadal survey in November 2021 concluded that SOFIA's science productivity did not justify its $85 million a year

NASA/SOFIA/PABST ET AL, JUPITER: NASA/SOFIA/USRA/FORCAST TEAM/JAMES DE BUIZER (INFRARED IMAGE)/ANTHONY WESLEY (VISIBLE LIGHT IMAGE), HONNIBALL ET AL. AND APPLIED COHERENT TECHNOLOGY CORP, CHRISTIAN FISCHER: IRINA SMIRNOVA-PINCHUKOVA, NIAMH SHAW X 2

What next now that SOFIA is over?

We spoke to two veterans of the airborne observatory about what happens now

Steven Goldman, staff scientist at the SOFIA observatory

"There is nothing like SOFIA planned for the near future. With the closeout of SOFIA, astronomers are going to lose the capability to detect important tracers and chemical transitions for at least the next decade. We are also losing our best platform for testing and improving new infrared instruments and technology. Balloon missions like GUSTO and ASTHROS, which are currently in development, will provide new far-infrared data in years to come, but won't fly nearly as often as SOFIA. Far-infrared astronomers will, however, still have tonnes of data to study from the last eight years of successful SOFIA flights."

Christian Fischer, project engineer on SOFIA's Field-Imaging Far-Infrared Line Spectrometer

"Our focus now shifts from data collection to ensuring that the knowledge we learned about observing far-infrared from the stratosphere is preserved. We need to get all the data from SOFIA in the best possible shape and make sure the astronomers have all the support they need to work with this complex information. There will be some very limited access to far-infrared skies by telescopes on stratospheric balloons, but they are not as reliable as SOFIA. For now, better and more reliable balloons or satellites are needed, but that will take some time."

▲ **Niamh (second from right) with fellow passengers, educators Nils Wuechner, Fabian Amann and Safia Quazi and, in brown, pilots Spike Tellier and Bill Becker**

operating costs. "We argued that the survey reached its conclusion based on older information and did not take into account SOFIA's latest discoveries", Meixner says. "I offered to provide the steering committee with an update, but was unable to do so."

Bernhard Schultz, SOFIA's deputy director of science mission operations, agrees. "We put into motion measurable improvements in the last four years. The last two years were crucial, but weren't taken into consideration."

By now it's 3am and some of my fellow educators have disappeared, catching an hour of rest to get them through to the 5:20am landing. I'm not sure how the science teams can stay so focused, but they just keep going.

How does Meixner feel about the future of astronomy without SOFIA's far-infrared data?

"The data we have gathered with SOFIA complements data gathered by telescopes such as the James Webb Space Telescope," she says. "But nothing can currently replace what SOFIA has shown us. The last NASA decadal survey seemed interested in developing a far-infrared or an X-ray probe. That won't be for 10 years though. The gap in data in the intervening years will be felt."

A farewell flight

By 5am SOFIA's telescope door has closed and data collection is complete. We take our seats, buckle up and I tune in to the cockpit comms. Spike chokes up as the plane touches down, and we all share a round of applause in his honour. I step off the plane and onto the runway at Palmsdale at 5:30am, when Spike and Bill appear. We invite them to join us for a group photo. "It's the end of an era, guys," Spike tells us, holding back tears. "End of an era."

Just a few weeks later, on 30 September, SOFIA completed its final flight. In its eight years of operation, it flew over 920 times, generating 60 postgraduate theses, 401 research publications, hosting 1,810 unique authors and co-authors, and involving over 3,000 people from the international research sector.

I asked Meixner and Schultz how they wanted SOFIA to be remembered. "For its scientific discoveries and how it pushed the field of far-infrared astronomy," Meixner says.

"Not just as a technological marvel, but also for its unique science," Schultz adds. "For being unique. For being amazing."

Niamh Shaw is a science writer and space communicator, and the author of *Dream Big: An Irish Woman's Space Odyssey*

The fundamentals of astronomy for beginners

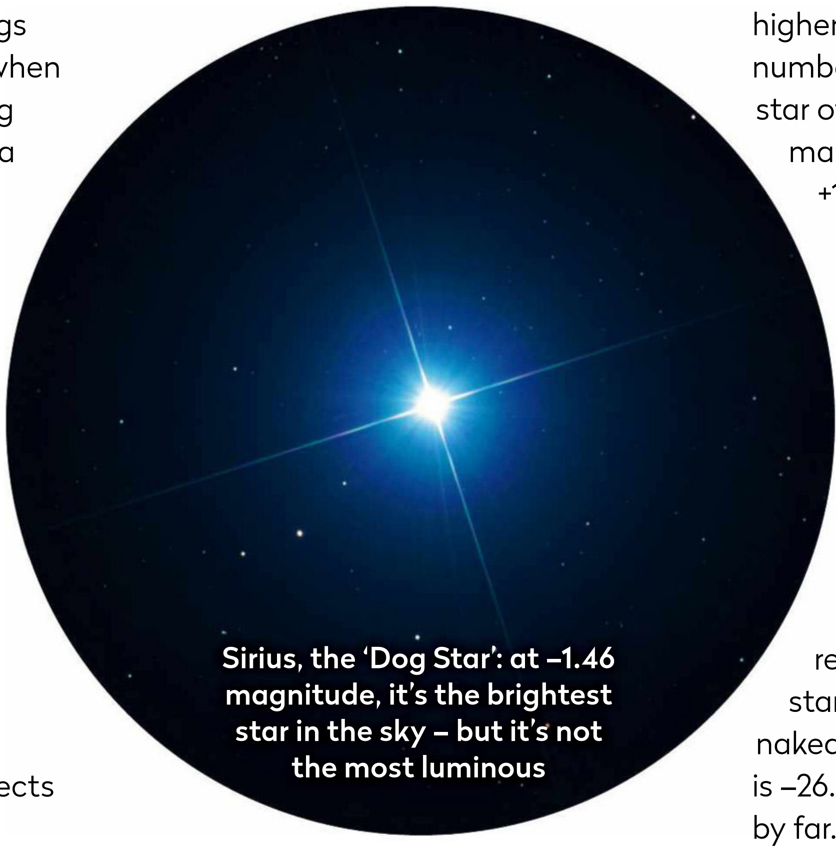
EXPLAINER

Brightness vs luminosity

All brightness is relative. **Scott Levine** reveals how we categorise our favourite stars

One of the first things many of us learn when we start stargazing is that Sirius (Alpha Canis Majoris) is night's brightest star. But what does it mean to say that something is bright, and what's the difference between brightness and luminosity?

Astronomers use different terms to talk about how much light we see from celestial objects and how much light those objects actually produce. But first, let's talk about magnitude.



Sirius, the 'Dog Star': at –1.46 magnitude, it's the brightest star in the sky – but it's not the most luminous

What is magnitude?

We generally talk about celestial objects in terms of **magnitude**. This doesn't measure how much light exists; rather it describes objects' brightness relative to each other. The Greek astronomer Hipparchus devised a scale in the second century BC, grouping stars by their brightness: the brightest stars at 1 and the dimmest stars at 6.

Today, objects with lower magnitudes are still listed as brighter than objects with higher magnitudes, and we use negative numbers for the brightest objects. So a star of mag. –1 is brighter than a star of mag. +2. Objects of about magnitude +1.5 or brighter are 'first-magnitude', objects from +1.5 to +2.5 are second, +2.5 to +3.5 are third, and so on.

Apparent magnitude, visual magnitude or simply magnitude, is the brightness we see when we observe our favourite stars. Hipparchus set Vega (Alpha Lyrae) at 0.0 on this scale and all other magnitudes are generally based on it (Vega's has since been refined to +0.03). Under dark skies, stars as dim as +6.5 are visible with the naked eye. The Sun's apparent magnitude is –26.74. It's the brightest object in our sky by far. The average full Moon's is about –12.75, and at its brightest Venus's apparent magnitude reaches about –4.9.

But just as a neighbour's window lamp appears brighter than a distant streetlight, what we see is a combination

The Moon and the next brightest object in the night sky, Venus, 160 times further away from us

We can see the effects of relative brightness when streetlights spoil our view of distant suns

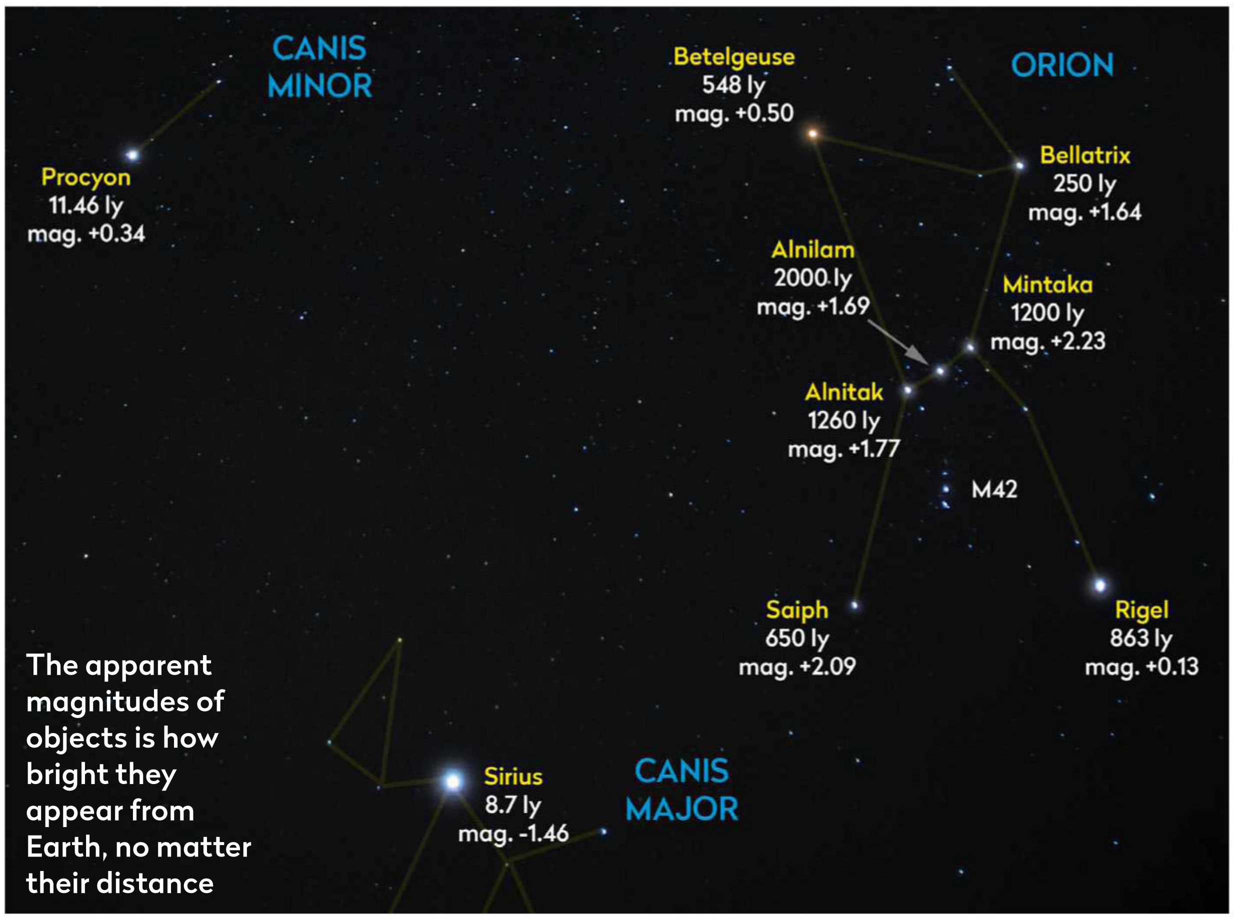
BRIGHTSTARS/ISTOCK/GETTY IMAGES, SHAUNL/ISTOCK/GETTY IMAGES, ANDREWMEDINA/ ISTOCK/GETTY IMAGES, PETE LAWRENCE, BERNHARD HUBL/CCDGUIDE.COM

How bright are the brightest stars?

The sky's brightest stars are not always its most luminous. Here are the five brightest stars visible from the UK, sorted by their apparent magnitude (**brightness**) and absolute magnitude (**luminosity**)

Star	Apparent magnitude
Sirius (Alpha Canis Majoris)	–1.46
Arcturus (Alpha Boötis)	–0.05
Vega (Alpha Lyrae)	+0.03
Capella (Alpha Aurigae)	+0.08
Rigel (Beta Orionis)	+0.13

Star	Absolute magnitude
Rigel (Beta Orionis)	–7.84
Capella (Alpha Aurigae)	–0.50
Arcturus (Alpha Boötis)	–0.30
Vega (Alpha Lyrae)	+0.59
Sirius (Alpha Canis Majoris)	+1.43

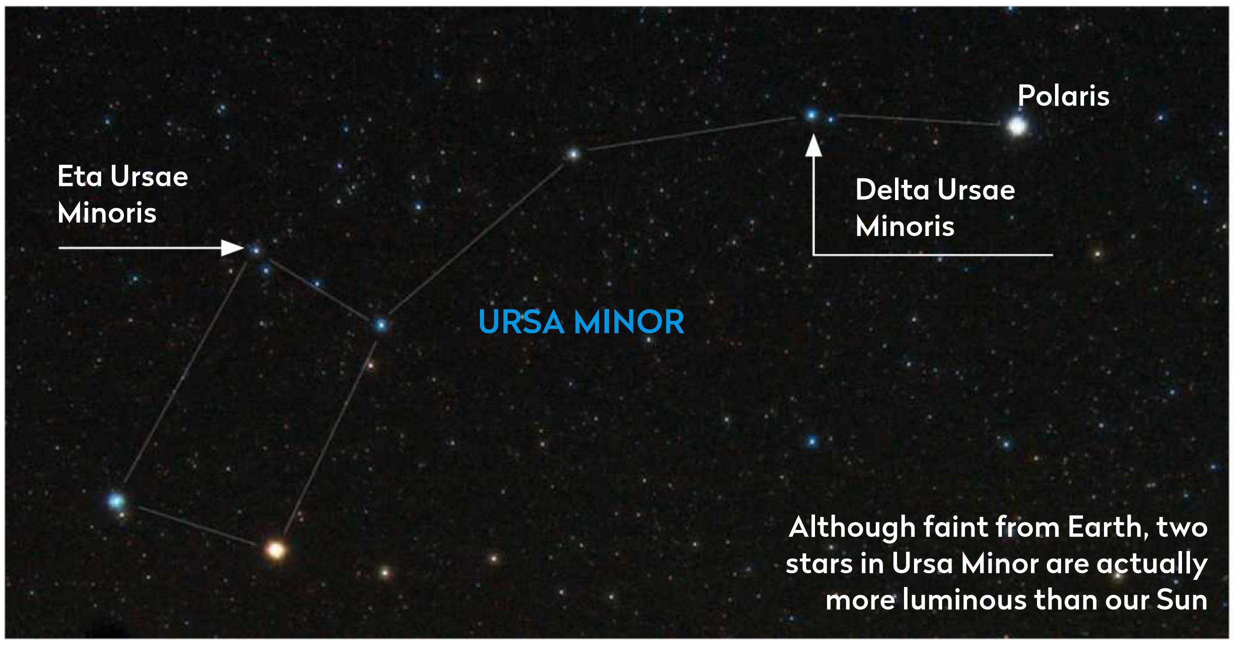


The apparent magnitudes of objects is how bright they appear from Earth, no matter their distance

of how much light an object creates, and its distance. So two identical stars at different distances can have different apparent magnitudes.

While apparent magnitude gives us an idea of how we see stars, no matter their distance, **absolute magnitude** puts them on equal footing. Instead of saying, "I think that one's brighter," we compare how bright objects would be if they were all 10 parsecs (32.6 lightyears) away (about the same distance as Arcturus (Alpha Boötis).

We can then talk about objects in terms of how much light they produce: how **luminous** they are. Some very distant stars create so much energy that we see them as among the night's brightest, despite them being so far away.



Although faint from Earth, two stars in Ursa Minor are actually more luminous than our Sun

Distance and luminosity

With this in mind, let's go back to the Sun. It's bright enough to bring us daylight, but its **absolute** magnitude is only about +4.83. That's about the same as the **apparent** magnitudes of Delta Ursae Minoris at +4.34, and Eta Ursae Minoris at +4.95. Both are more luminous than the Sun. From Earth, though, they're quite faint, just like most of Ursa Minor's stars, and they give us an idea of what our Sun would look like if it lay near Arcturus.

Two of the sky's brightest stars, Sirius and Rigel (Beta Orionis), appear near each other and are a spectacular sight on a dark night. But Sirius (**apparent** magnitude –1.46) is about 8.6 lightyears away, while Rigel (**apparent** magnitude +0.13) is far behind, around 700 lightyears.

Sirius is about twice the size of the Sun and has an **absolute** magnitude of +1.43. Meanwhile, Rigel a supergiant 18–24 times more massive than the Sun, has an **absolute** magnitude of –7.84. So while nearby Sirius appears brighter, the absolute magnitudes tell us distant Rigel is more luminous, and far outshines the brightest star in the night sky.

Next time you look up at the stars, consider absolute and apparent magnitude and imagine just how bright the stars you're observing actually are.

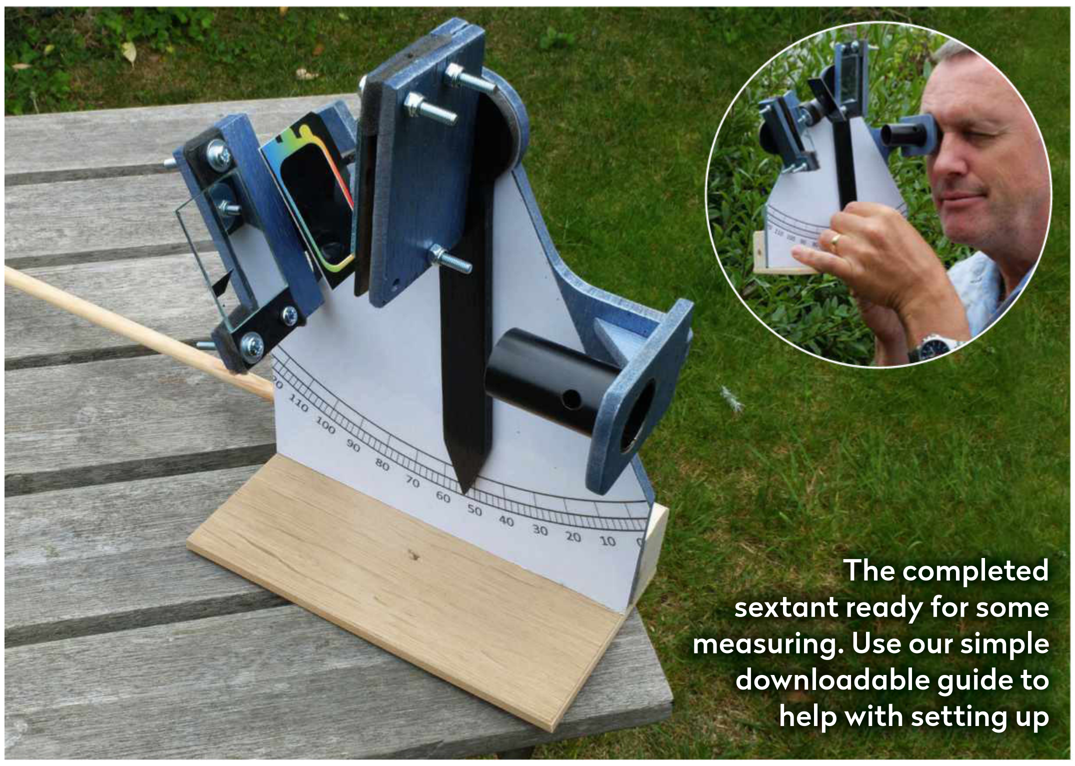
Scott Levine is an astronomy writer and naked-eye observer based in New York's Hudson Valley

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

How to build a sextant

Measure altitudes the ancient astronomers' way with this traditional navigation instrument



The completed sextant ready for some measuring. Use our simple downloadable guide to help with setting up

This month's project is a sextant that you can use to measure the altitude of objects in the sky. At noon (taking care to use the built-in solar filter), you can measure the height of the Sun and use this to find your location on Earth.

Our design uses two mirrors: the index mirror, mounted on a moveable pointer arm, and the fixed horizon mirror, which is half-clear, producing two images. In use, the left-hand image (usually of the horizon) is viewed through the clear side, while the right-hand image arrives via reflection in both mirrors (passing through a solar filter in between, when viewing the Sun). By adjusting the angle of the index mirror, you can align the image of the object you are measuring with the horizon on the left. The pointer arm then indicates the altitude of the object on a printed scale, measured in degrees above the horizon.

The sextant is made from thin MDF. Our downloadable templates show the parts to cut out, along with a printable scale. We cut inexpensive craft mirrors to size with a glass cutter. This is a bit tricky, but a glass supplier may be able to cut these for you. Mask off one half of the back of the horizon mirror, then gently scrape away the painted layer and the silvering, taking care not to scratch the glass. Both mirrors are stuck to thin MDF backings that are held to the mirror mounts by M4 screws and nuts, with spongy foam spacers sandwiched between that allow them to be finely adjusted when setting up the instrument. Our downloadable guide explains how to set up. Once you get your sextant working, there are numerous online tutorials for using it.

Mark Parrish is an amateur astronomer and bespoke designer based in West Sussex

ALL PICTURES: MARK PARRISH

Where on Earth?

If you can't see the horizon, you can still use your sextant. We achieved this by adding a long arm extending forwards, with an upright rod and a horizon indicator wire (a paperclip!) attached at the exact height of the eyepiece centreline. We stuck a piece of black tape to the clear side of the horizon mirror, also at this height. If you visually line up the wire and top of the tape, you are very close to horizontal. The indicator wire then serves as the horizon for measurements. Our guide also explains alternative methods.

Using the sextant, we were able to measure when noon occurred for our location (we estimated approximately 12:08 UT) indicating a longitude of 2.0° west. The height of the Sun measured 52°. We subtracted this from 90° to find the latitude (adding on 12.3° correction for the date, which we looked up at **thenauticalalmanac.com**). Our calculated position was only about 100km from our actual location – not too bad considering the resolution of the scale and the overall size of our planet!

MORE **ONLINE**

Download diagrams, a setup guide and photos to help with your build. See page 5 for details

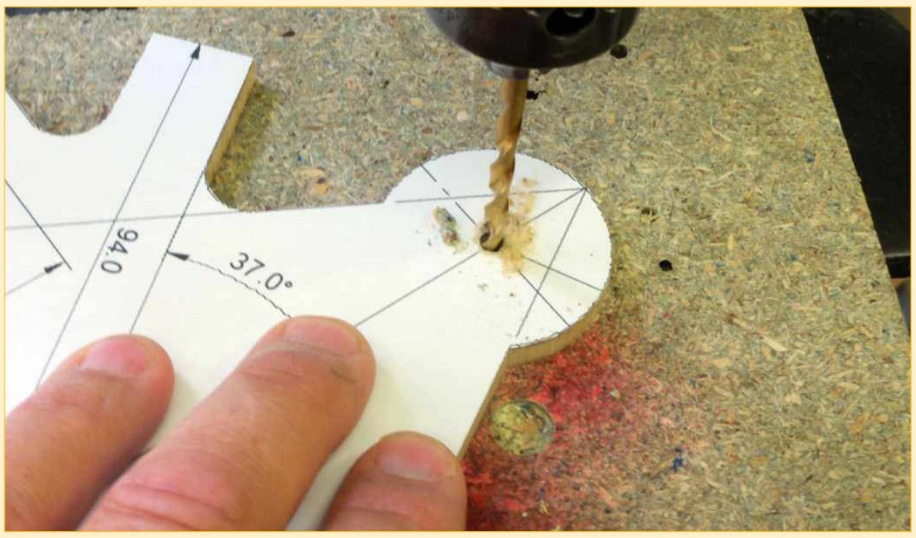
What you'll need

- Tools: ruler, compasses, pencil, coping saw, junior hacksaw, drill and drill bits, glass cutter, craft knife blade.
- Two pieces of approximately A4-sized thin MDF or plywood, a pair of approved solar eclipse glasses, two craft mirrors 50 x 35mm, eight M4 x 20 screws, nuts and washers, a piece of spongy foam.
- Piece of thin tube approximately 20mm diameter to make the eyepiece.
- Spray paint, glue.

Step by step

Step 1

Carefully mark out the MDF: print out the templates for the main parts (be sure to set your printer scale to 100% for all printouts), cut them out and glue them on to the MDF. Cut out all the parts with a coping saw, or similar, and sand the edges smooth.

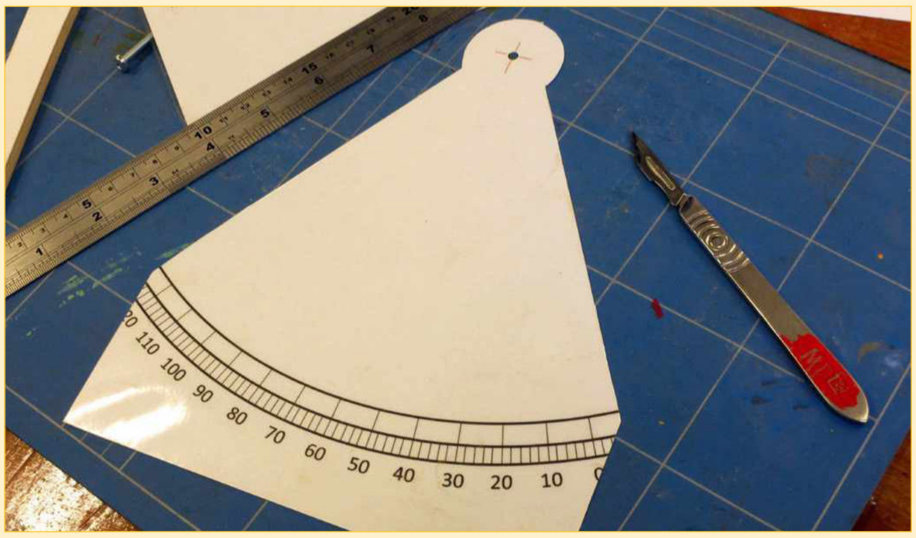


Step 2

Carefully drill the holes in the main panel and the mirror mount parts. Use a 4mm drill for pivots but a 4.5mm drill bit for the mounts, so that the angle of each mirror can be adjusted a little, relative to the mount.

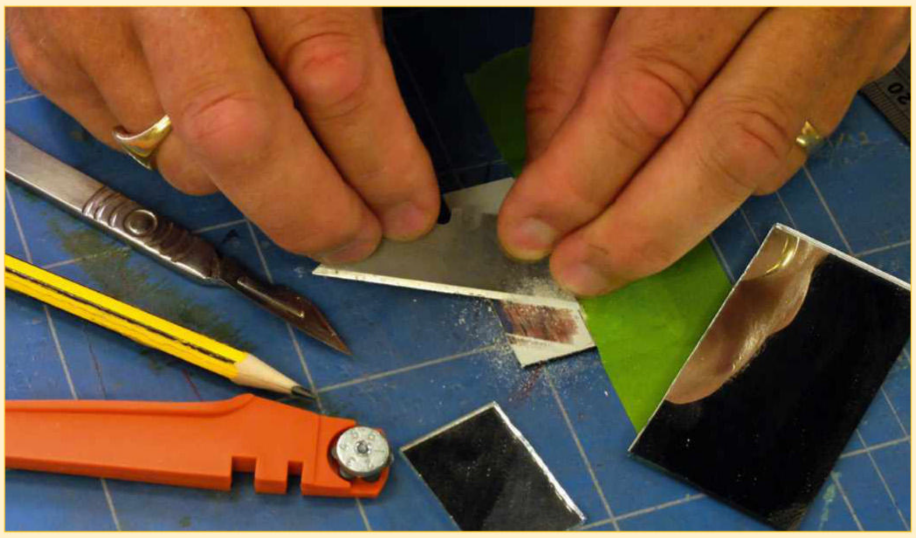
Step 3

Glue together the two parts of each mirror mount and leave to dry. You can also glue on the eyepiece parts and the support for the solar filter. Painting the wooden parts makes them look nice but also provides a bit of long-term protection.



Step 4

Print off the scale and stick directly to the main panel. Laminate it first if possible. Alternatively, use a protractor to mark out your own accurate scale (or even stick a protractor on), but note that at the scale we've used for this build the 10° markings are 5° apart.



Step 5

Cut the mirrors to size, being careful of sharp edges. Use tape to mask half the back of one. Cut through the paint backing along the line, then gently scrape away the paint and silvering with a blade. Metal polish can be used to remove any stubborn bits.

Step 6

Glue the mirrors to their backings and cut one half of the eclipse glasses to make the filter. Assemble all the parts, using foam spacers between mirror backings and mounts so they can be adjusted. Use our downloadable guide to set up the instrument.

ASTROPHOTOGRAPHY CAPTURE

Photographing Mars

Whatever equipment you have, Mars is an irresistible subject as it approaches opposition

The excitement is increasing as Mars approaches opposition on 8 December. This is because Mars oppositions are a big deal. The term opposition describes when a planet appears on the other side of the sky to the Sun. Geometrically, this also means we're closer to a planet at opposition than at any other time. For more distant worlds, the difference that makes to its appearance isn't so significant. An exception is Saturn, but only because of the 'opposition effect', a phenomenon that makes its beautiful rings glow brighter at opposition than at other times. However, Mars is a nearer world and its opposition appearance is considerably better than at other times.

Mars oppositions occur every 2.1 years. At optimal oppositions it appears to have an apparent diameter over 20 arcseconds across. As well as appearing to expand in size through the eyepiece, to the naked eye Mars also brightens impressively around opposition. Less favourable oppositions may present the planet with an apparent arcsecond diameter in the low-teens. This year's opposition has Mars reaching a maximum apparent diameter of 17.2 arcseconds on 1 December, when Mars is closest to Earth. At this time it'll appear to shine at mag. –1.8.

If you're wondering what the best way is to image Mars around opposition, the answer depends on what kit you have available. The planet's impressive orange-hued, star-like dot should be relatively easy to photograph with a modern smartphone, even if it doesn't pick up many surrounding stars. Here, a good strategy is to catch Mars low in the sky, bringing foreground objects into the view to give the planet context.

A bright Moon can be used to set the scene too. Grab a show of the full Moon near bright Mars, low above a visible horizon and you'll have a winning shot. Dates when this will happen are 10 and 11 November, and the nights of 7 and 8 December. Mars is occulted by the Moon early on 8 December, so prepare to extend the evening session on 7 December into the early hours of the following morning for some real Moon–Mars drama.

▲ **Mars, three ways: captured with (left to right) a smartphone, a DSLR and then a high-frame-rate camera with a large telescope**

ALL PICTURES: PETE LAWRENCE

A DSLR or equivalent camera with a mid- to wide-angle lens will be able to capture some serious shots of Mars, with or without the Moon. The planet is currently moving fairly slowly through Taurus, a feature-rich part of the sky. Mid-angle lenses should capture the planet and most, if not all, of the stars surrounding it. This includes the beautiful Pleiades and Hyades open clusters, as well as bright Aldebaran (Alpha (α) Tauri) which conveniently, for comparison purposes, also appears orange. A wide-angle lens could extend the sky coverage to include Orion too.

A DSLR or equivalent allows you to get a great shot of the general star-scene with Mars, using relatively short exposures on a fixed tripod. From a dark-sky site, consider using a tracking mount to extend exposure time. This will allow you to reduce ISO, producing better colour tone and less noise in your images. It will also allow you to go deeper in terms of the stars and nebulosity that are revealed.

Equipment: Camera; fixed or tracking mount

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

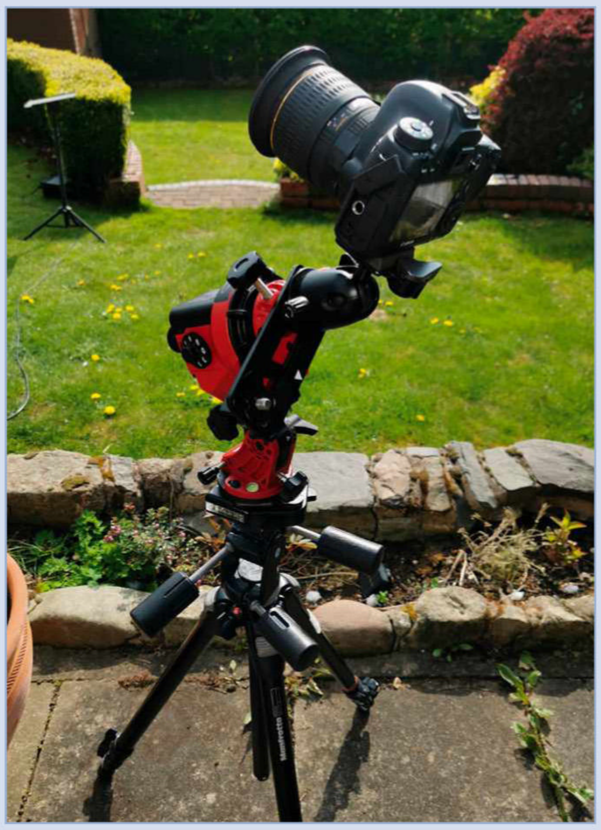
Send your images to:
gallery@skyatnightmagazine.com

Step by step

Mars low in the sky, taken with a Huawei P30 Pro smartphone

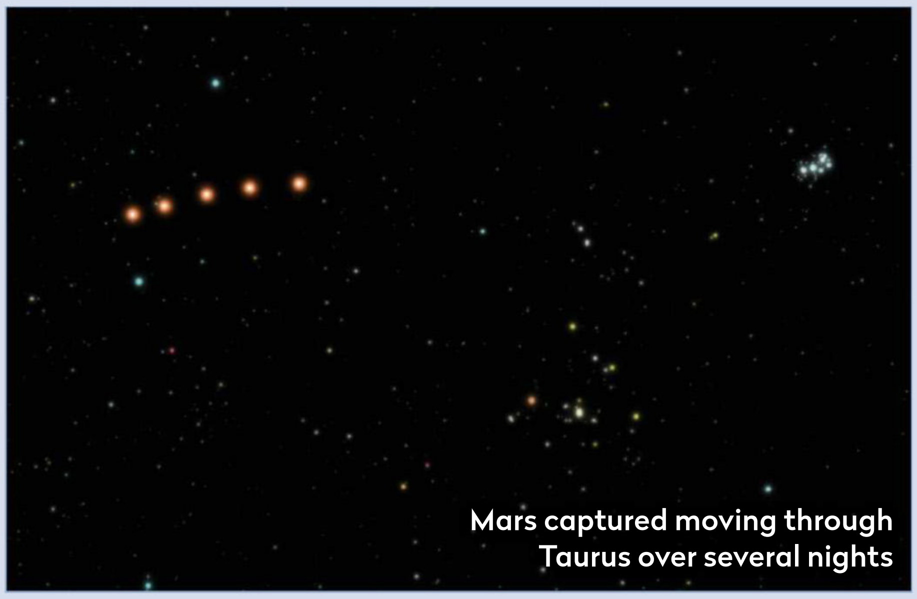
STEP 1

A smartphone will record Mars as a dot. Catch the planet shortly after rising or before setting; include foreground objects for more drama or the Moon if it's nearby. Even a cheap tripod phone holder will help with stability. The volume control on a headphone lead can act as a remote shutter release for many phones.



STEP 2

A DSLR or equivalent with a mid- to wide-angle lens opens up many possibilities. Taurus is feature-rich, with strong patterns and two large and bright naked-eye open clusters. Frame your shot to include the Pleiades and Hyades and you'll be onto a winner. A tracking mount allows you to use a lower ISO and longer exposure to preserve tonal colour.



Mars captured moving through Taurus over several nights

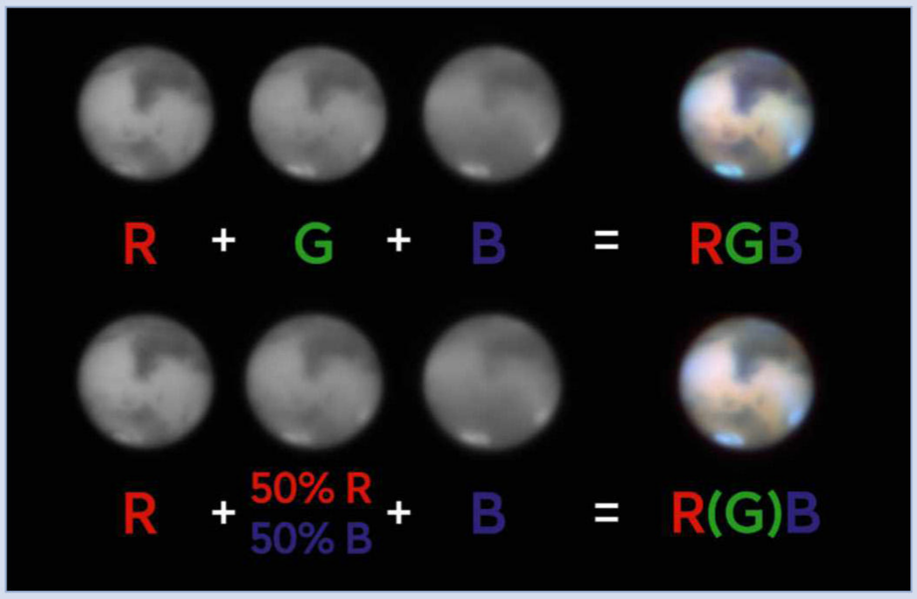
STEP 3

Shoot Mars against the stars in Taurus over several nights, keeping similar framing and settings. Load them into a layer-based editor, one image per layer. Align the shots by their stars. Set the blend mode of all layers except the base one to lighten, to show Mars moving through Taurus.

An atmospheric dispersion corrector (ADC)

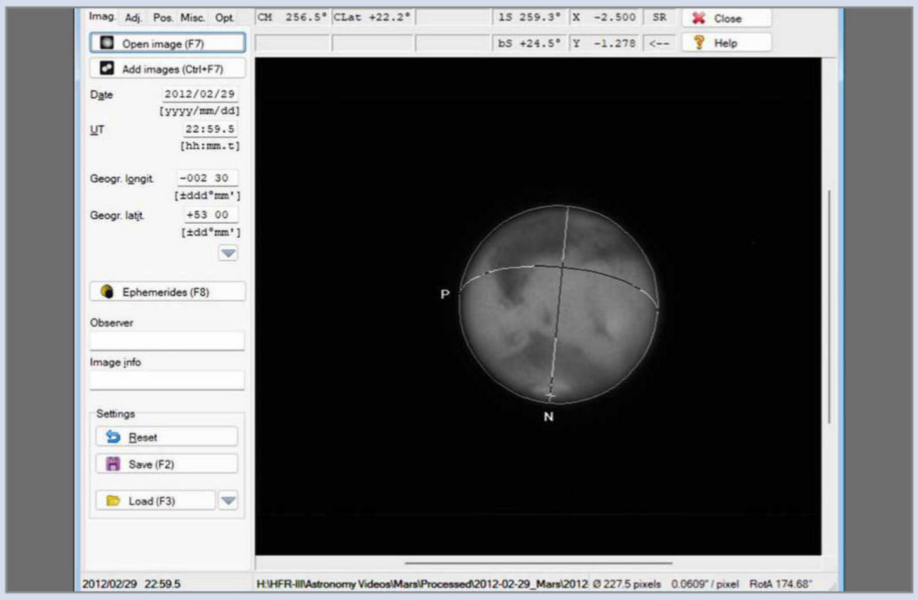
STEP 4

Larger scopes can use a high-frame-rate camera to image Mars's surface. A one-shot colour camera can be used when it is highest in the sky. When lower, an atmospheric dispersion corrector may be required to remove colour fringing. Keep capture times below 90 seconds to avoid motion blur due to the planet's rotation. IR/UV blocking filters (L) will prevent infrared bleed.



STEP 5

A mono high-frame-rate camera with an infrared (IR) pass filter will give high-contrast results. Full RGB colour captures require imaging through red (R), green (G) and blue (B) filters, again keeping the entire sequence capture time below 90 seconds. It may help to capture R+B and synthesise G using a 50:50 R+B mix.

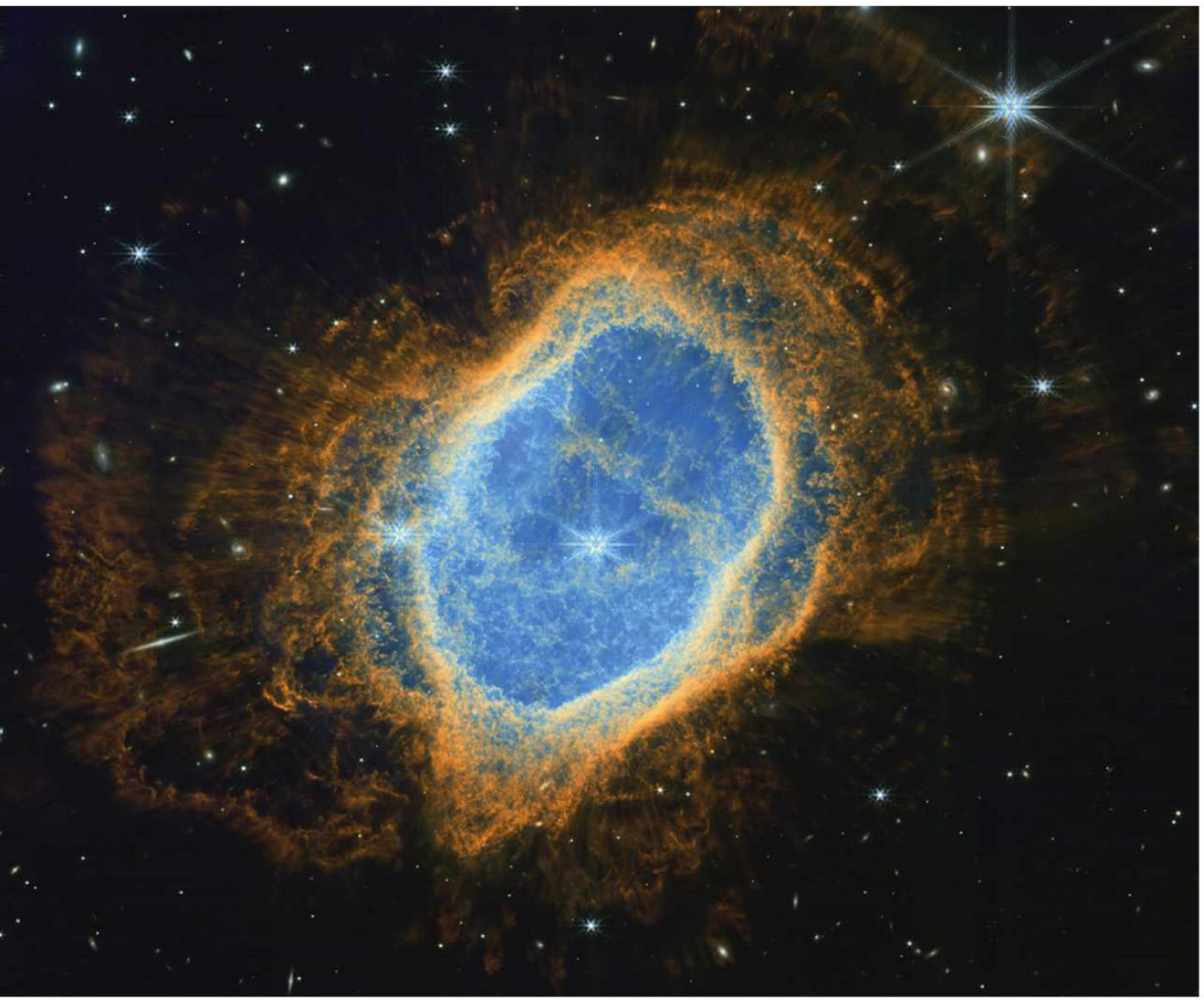


STEP 6

Accurate focus and steady seeing give best results. Use a stacking program such as AutoStakkert! to process. Assemble RGB images in a graphics editor, each colour image in the appropriate colour channel of an RGB blank. Freeware like WinJupos offers this, as well as advanced measurement and derotation options.

Making your own images from JWST data

Download and put your own spin on observations from the world's largest space telescope



▲ **The author's rendition of NGC 3132, the Southern Ring Nebula, processed from freely-available JWST data**

ALL PICTURES: WARREN KELLER/NASA/ESA/CSA/STSCI, NIRCAM FILTERS CHART COURTESY OF THE SPACE TELESCOPE SCIENCE INSTITUTE

We live in rather amazing times, with private citizens travelling to space and citizen scientists contributing to the knowledge base of professional astronomy. Now, just as it did with Hubble, NASA has made data from the James Webb Space Telescope (JWST) available for download, for anyone to process for themselves. Here we walk you through, step by step, how to do it.

Start by searching for 'MAST Portal' in your web browser or visit **mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html**, an archive named after Barbara Mikulski, a retired US senator and staunch supporter of space exploration. Clicking on 'Advanced search' at the top of the page opens a new window. On the far right, type 'JWST' in the 'Mission' box and press 'Enter'. At far left, under 'Columns', select 'Release date' and scroll down to the box of the same name. Type '2022-07-13 14:00:00' as the beginning date and time – 13 July 2022 being the day on which the first observations were released to the public.

With the end date at default (the year 2050), note the number of 'Records found' at the top of the page. At the time of writing, there were already over 120,000 in the archive. As NGC 3132 is our target and was one of the first data sets released, entering an end date of '2022-07-13 16:00:00' displays a manageable 2,325 records. Clicking 'Search' at top left reveals the individual file folders and you'll need to narrow the field yet again.

Under 'Instrument' in the 'Filters' box at left, choose the near-infrared data by checking 'NIRCAM'. Depending on the width of your monitor and browser window, you may need to use the scroll bar at the bottom to slide over to the 'Target name' column. Also note the 'Filters' column. I found F187N, F356W and F444W to be the most useful filters. Click on the floppy disc icons of records 13, 15 and 18 to download the zipped folders to your computer (see Figure 1).

Colour choices

Unzip the folder to a suitable location on your computer then open the parent folder, then a second folder with the same name and, finally, the JWST directory. Next, open the 'Nircam' folder, discarding all but the FITS file ending in 'i2d.' Double-clicking that file will open seven individual files in your program of choice, mine being PixInsight.

Of these, the seventh and last to open has a _SCI suffix and is the only file that you'll need. When finished, you will be left with three files to post-process, each ending in 'i2d.fits', with the filter names f444w_f470n, f356w and f187n.

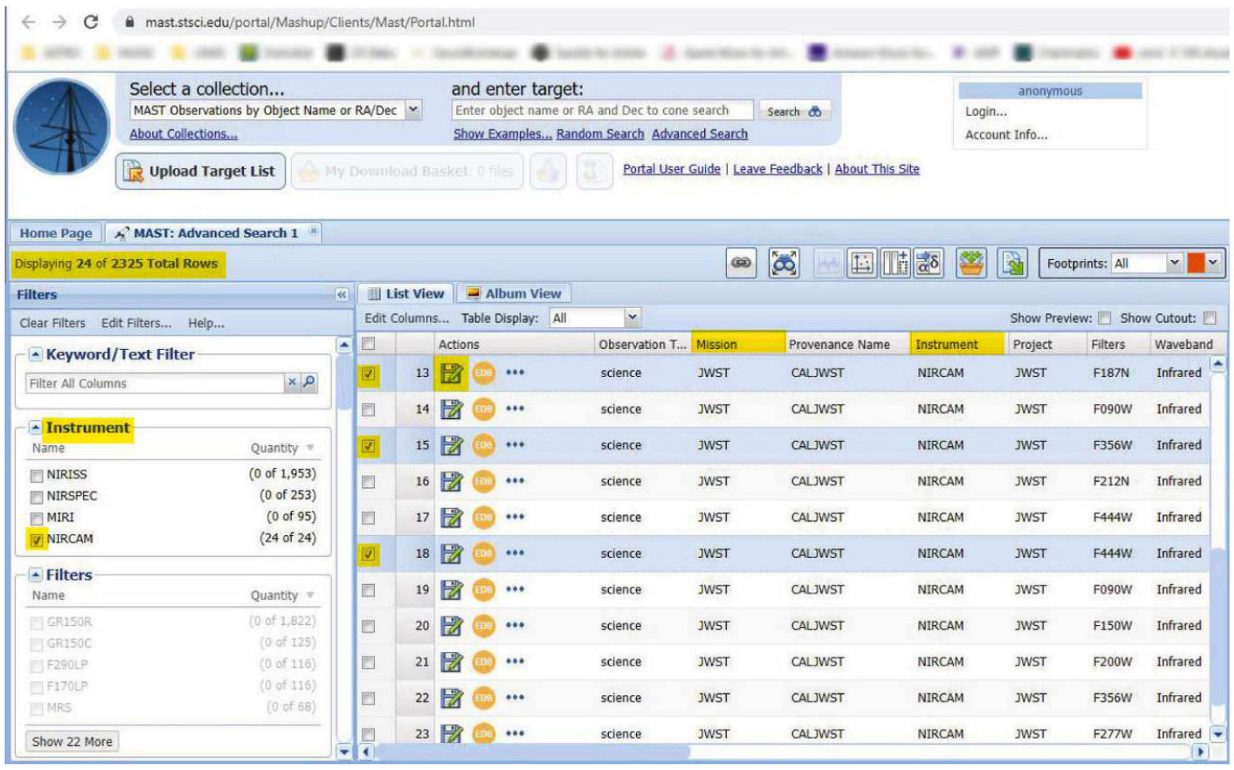
Those of us who process narrowband images will understand the concept of 'mapping' data that's invisible to the human eye to colours that we can perceive. The same is true here. Rather than the emission lines of the Hubble palette, we're now dealing with Webb's near-infrared information.

3 QUICK TIPS

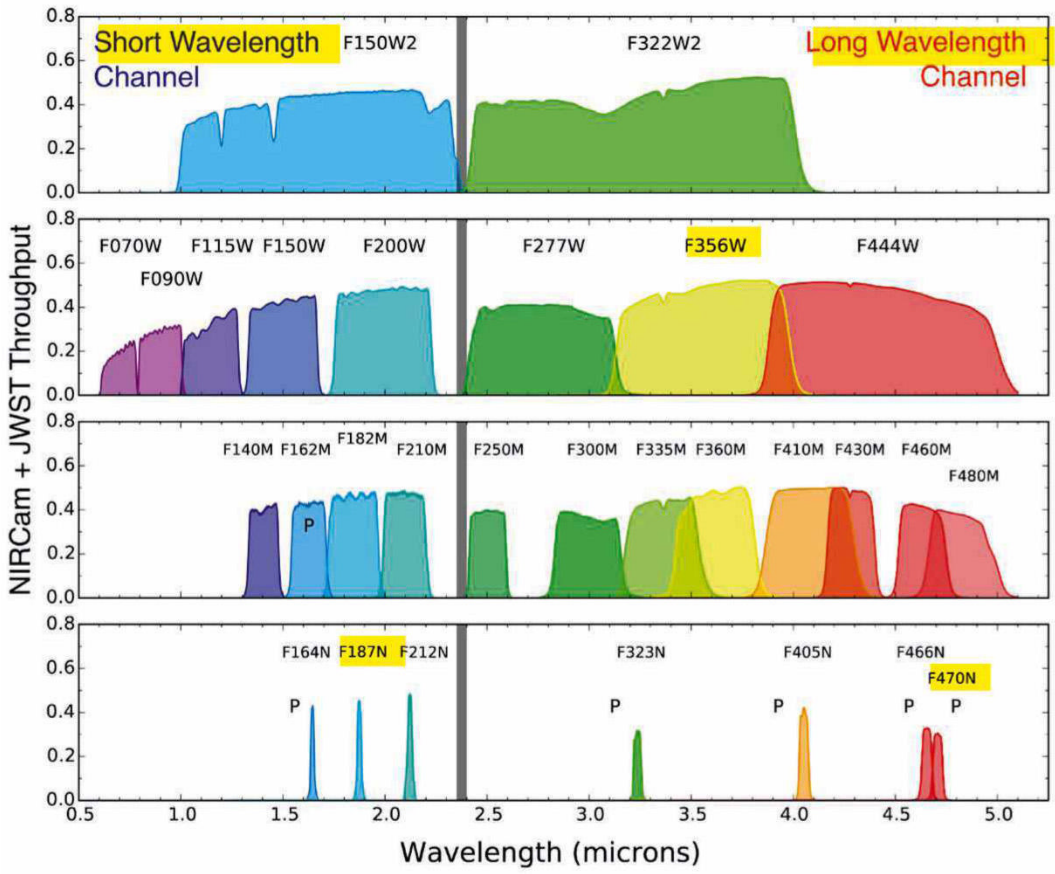
1. Knowing the release date of a particular data set will help narrow your records search considerably.

2. Note that the strength of the NIRCam's infrared signal may render noise reduction unnecessary.

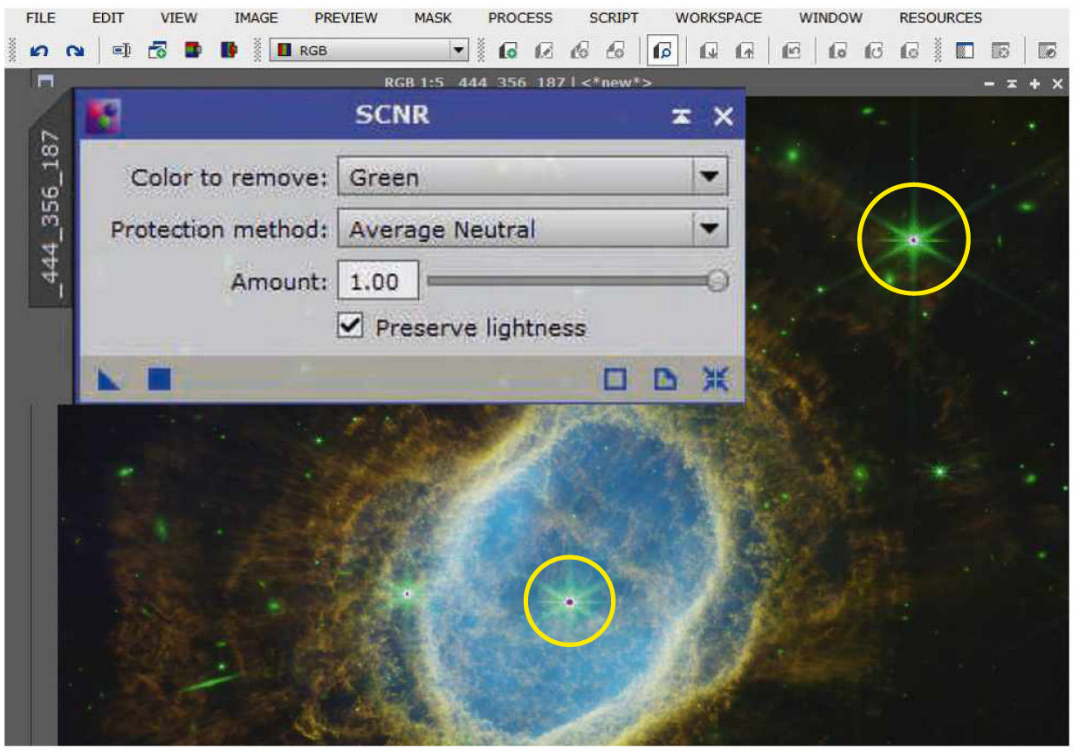
3. While gathering the data is a rather tedious process, the end result is well worth the effort!



◄ **Figure 1: Once you've homed in on the data you need, download the desired folders by clicking the little green icons**



▲ **Figure 2: NIRCam filter names and the colours associated with them. Use this to help you choose the colours to assign to JWST's near-infrared data channels**



▲ **Figure 3: SCNR in PixInsight was used to remove an overly green cast from the stars. The odd diffraction spikes are a result of JWST's segmented mirror**

How best to assign these filters? For guidance, search online for 'NIRCam Filters – JWST User Documentation' or visit **jwst-docs.stsci.edu/jwst-near-infrared-camera/nircam-instrumentation/nircam-filters**. There you will find a full-colour graph illustrating the transmission lines of each filter from short to long wavelengths.

While there's no single, correct way to proceed, it made sense to me to assign the shortest wavelength data (F187N) to the blue channel, as blue is on the shorter end of the visible spectrum. Conversely, I mapped the long wavelength F470N data to red and the medium F356W to green. I found this to be the most aesthetically pleasing colour blend for this particular object, and strikingly similar to the Hubble SHO palette (see Figure 2).

After marrying the channels with PixInsight's 'Channel combination' process, the images were cropped of edge artefacts and stretched with 'Histogram transformation' (HT). Transferring a 'Boosted autostretch' from the STF (Screen transfer function) to HT with the RGB channels unlinked provided a great start to good colour.

PixInsight's SCNR (Subtractive chromatic noise reduction) was then applied to reduce an undesirable green cast in the stars (see Figure 3). From there, a range mask was applied, so that contrast, sharpness and colour saturation could be boosted in the nebula only.

As the data was so clean, no noise reduction was needed for our final image, which you can see on the page opposite. If you're a Photoshop-based processor, be sure to view Nico Carver's excellent tutorial, 'Can I process the JWST data better than NASA?' on his 'Nebula Photos' YouTube channel (**www.youtube.com/watch?v=DVuonz26P0w**).

Warren Keller is an astrophotographer and image-processing educator. See **www.mastersofpixinsight.com**

Your best photos submitted to the magazine this month

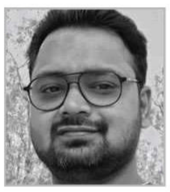
ASTROPHOTOGRAPHY GALLERY

More ONLINE
A gallery containing these and more of your images

PHOTO OF THE MONTH

△ The Heart and Soul Nebulae

Basudeb Chakrabarti, remotely via IC Astronomy Observatory, Almería, Spain, 21 February 2022



Basudeb says: "Located about 6,000 lightyears from Earth, the Heart and Soul Nebulae create a vast star-forming complex that makes up part of the Perseus spiral arm of our Milky Way Galaxy. I have been obsessed with the sheer beauty of the nebulae since I started astrophotography one and a half years ago. I processed the Heart Nebula six months ago. But this time I have done a two-panel mosaic to capture these two beautiful nebulae in a single frame. "

Equipment: FLI PL16083 camera, Takahashi FSQ-106EDX4 refractor, Paramount MX+ mount
Exposure: Heart 26h 50'; Soul 20h 40'
Software: PixInsight, Photoshop

Basudeb's top tips: "My tip is that it's better to gather as much data as possible from a single target rather than taking less data from multiple targets. Before combining the individual channels, I would suggest visualising your final colour rendition of the image. I recommend taking additional time and extra precautions during the deconvolution process in PixInsight to render sharper and more beautiful stars. During the postprocessing, it's a good idea to make multiple small changes, step by step, instead of applying a big change at once."

△ Aurora and a Perseid meteor

Olli Reijonen, Syrjävaara, Finland, 12 August 2022

Olli says: "The strengthening aurora borealis was already visible in the sky, and while photographing the Northern Lights I saw two handsome early Perseids, one of which, with good luck, was exposed in a frame. At the same time, the last noctilucent clouds of autumn began to rise."

Equipment: Olympus OM-D E-M5 mirrorless camera, 8mm fisheye lens, tripod **Exposure:** ISO 800 f/1.8, 1" **Software:** Photoshop

△ The Fireworks Galaxy

Roland Gooday, Wantage, Oxfordshire, 6 August 2022

Roland says: "I was hoping to bring out as much detail as I could while retaining a natural-looking colour, with as little exposure time as the weather allowed."

Equipment: Altair Hypercam 533C camera, Celestron EdgeHD 8-inch aplanatic Schmidt-Cassegrain, Sky-Watcher EQ6-R mount **Exposure:** 5h 30' **Software:** PixInsight

◁ Trio of planets

Ollie Bacon, Kirkby, Merseyside, 12 August 2022

Ollie says: "I put the images together in a montage to show the current differences in the apparent sizes of Jupiter, Mars and Saturn, as well as the variations in colour of the three planets."

Equipment: ZWO ASI120MC-S camera, Sky-Watcher Skymax 127 Maksutov-Cassegrain, Sky-Watcher EQ6-R Pro mount **Exposure:** 1,200 frames **Software:** PIPP, AutoStakkert!, RegiStax, Photoshop

△ NGC 6729

Ethan Wong Yew Hoe, Mersing, Malaysia, 26 August 2022

Ethan says: "This molecular cloud in Corona Australis has always intrigued me. It requires excellent sky conditions and sufficient aperture to pull in those dim and dusty structures. A bonus object is nearby globular cluster NGC 6723."

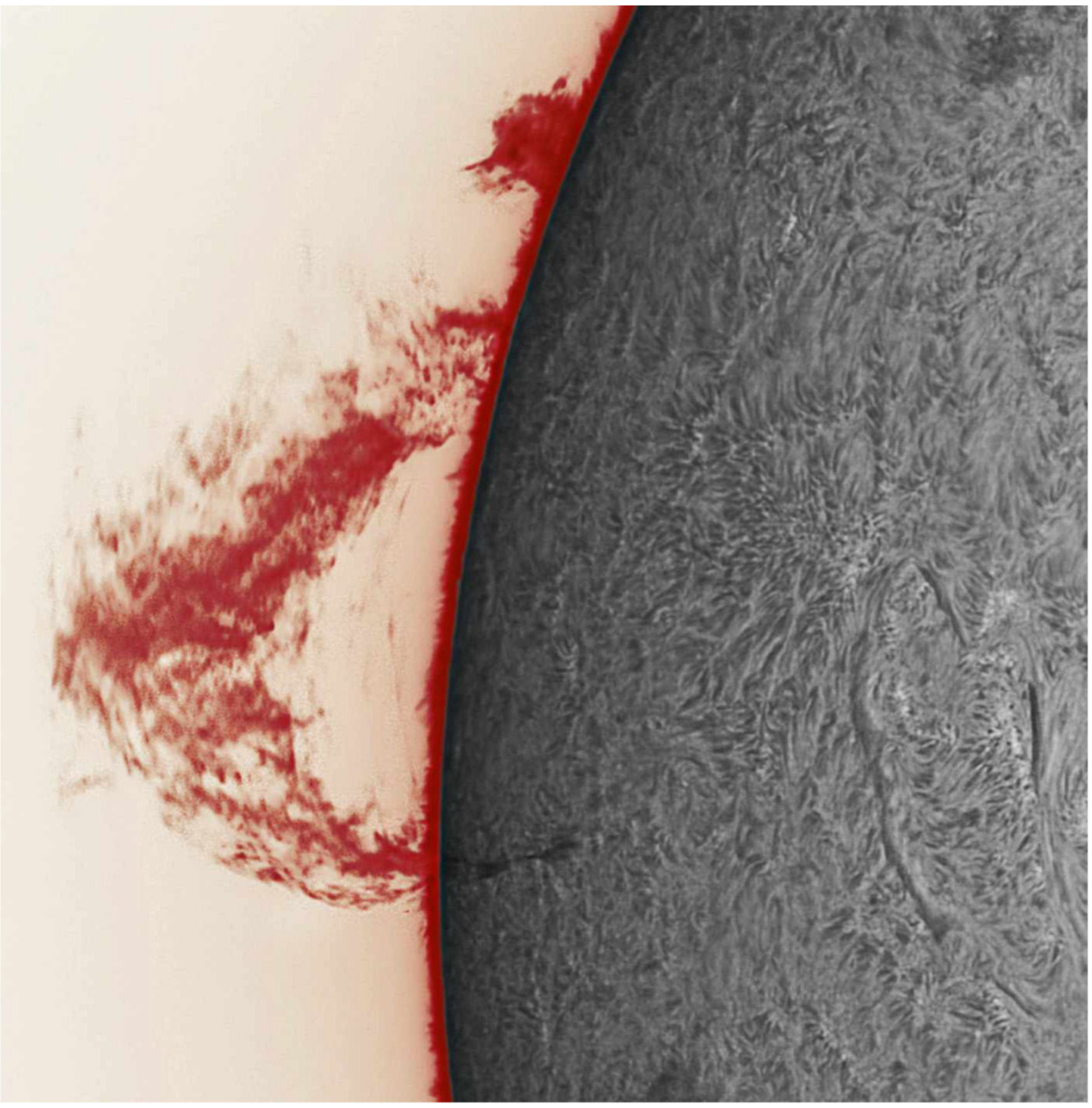
Equipment: QHY533C camera, StellaMira 90mm triplet refractor, iOptron CEM26 mount **Exposure:** 35x 180"
Software: PixInsight, Photoshop

Solar prominence in red ▷

Kevin Earp, Bedford, 4 August 2022

Kevin says: "I used a mono colour scheme for the disc, with the prominence colourised against a white background, to try to accentuate its details."

Equipment: ZWO ASI174MM camera, Sky-Watcher Esprit 100 refractor, DayStar Quark Chromosphere eyepiece, Sky-Watcher NEQ6 Pro mount **Exposure:** best 20% of 500-frame video **Software:** SharpCap, AutoStakkert!, RegiStax, Photoshop



△ August supermoon

Vicki Pink, Southampton, 12 August 2022

Vicki says: "My imaging run was due to finish around 2:30am, but I caught sight of the full Moon just peacefully hanging there in the gap between the houses. How could I resist taking some snaps?"

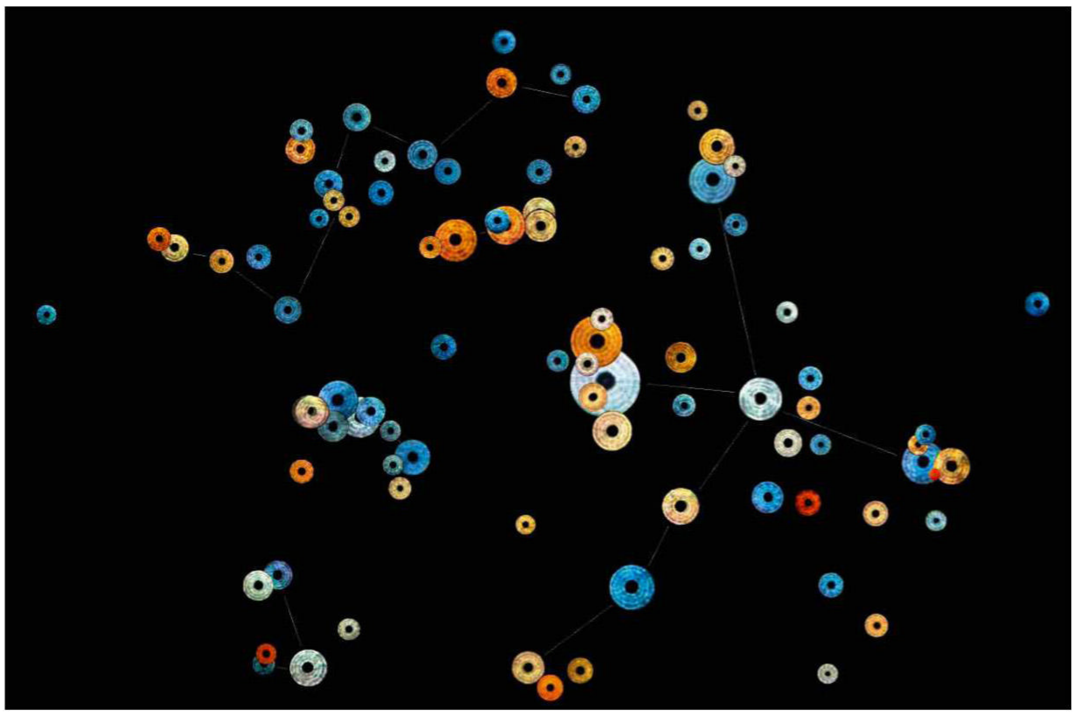
Equipment: Altair Hypercam 269C Pro camera, Sky-Watcher 72ED Evostar refractor, Sky-Watcher HEQ5 Pro mount **Exposure:** 16ms, two-panel mosaic, 300 frames each **Software:** SharpCap, AutoStakkert!, RegiStax, Photoshop

▽ Constellations in colour

Paolo Palma, Naples, Italy, 2020–2022

Paolo says: "In the last two years I have captured all the stars up to mag. +5 visible from Naples, about 1,300 in all. I defocused the stars to make the colours clearer and make mosaics of the constellations. This is Aquila, Delphinus, Sagitta, Vulpecula and Equuleus."

Equipment: Samsung A5 smartphone, Sky-Watcher Stargate 450P Synscan Dobsonian **Exposure:** ISO 8000 f/2, 1/11" **Software:** GIMP

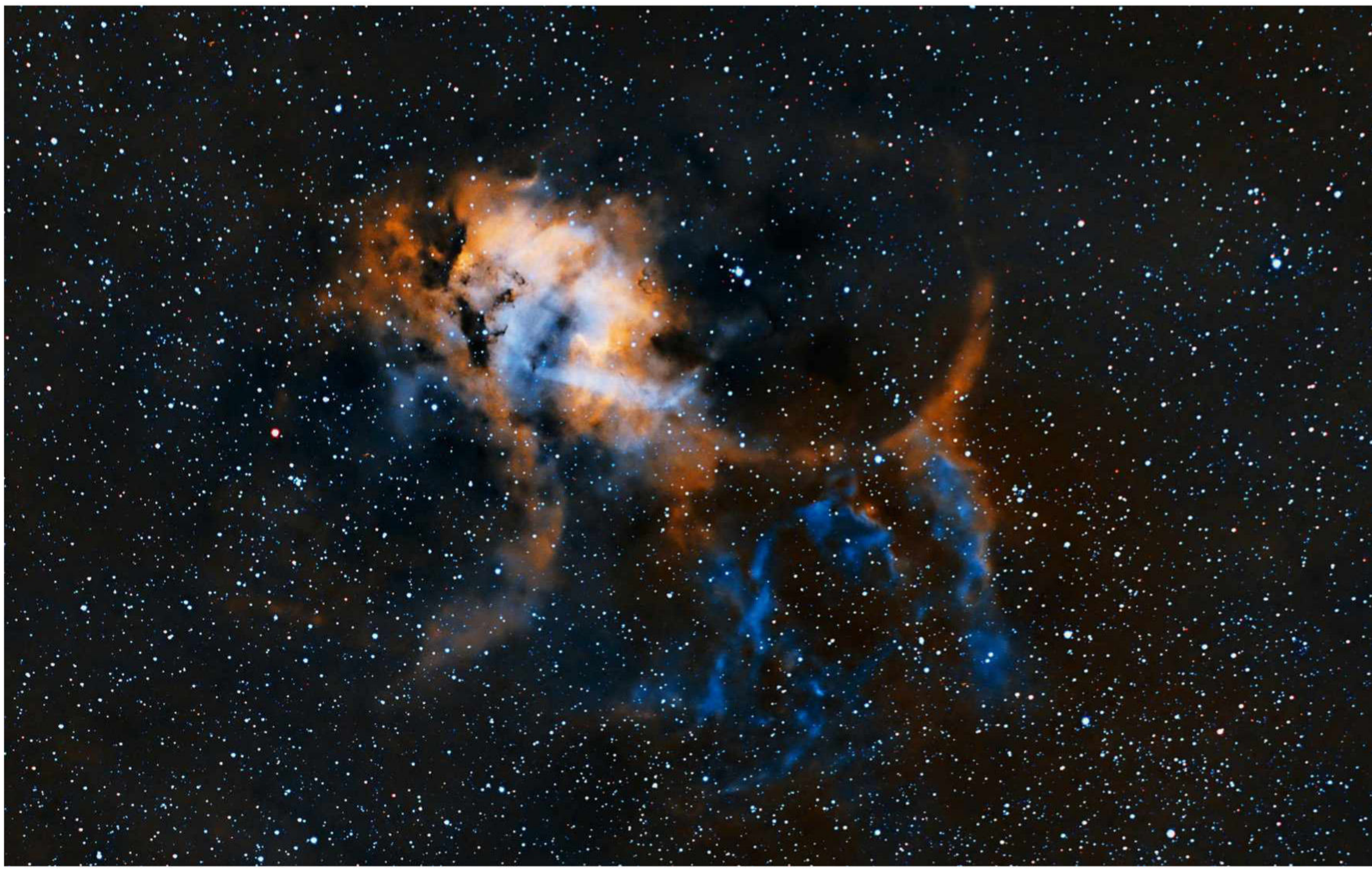


The Lion Nebula ▷

Richard Guest, Kingswinford, West Midlands, 15 June 2022

Richard says: "The Lion Nebula in the constellation of Cepheus was a new target to me. I used an IDAS NBZ Nebula Boost filter to draw out the ionised hydrogen and oxygen. After using PixInsight and Topaz DeNoise, the nebula just seemed to leap out of the image!"

Equipment: ZWO ASI2600MC camera, Celestron NexStar Evolution 8-inch EdgeHD Schmidt-Cassegrain **Exposure:** 90x 60" **Software:** PixInsight, Topaz DeNoise



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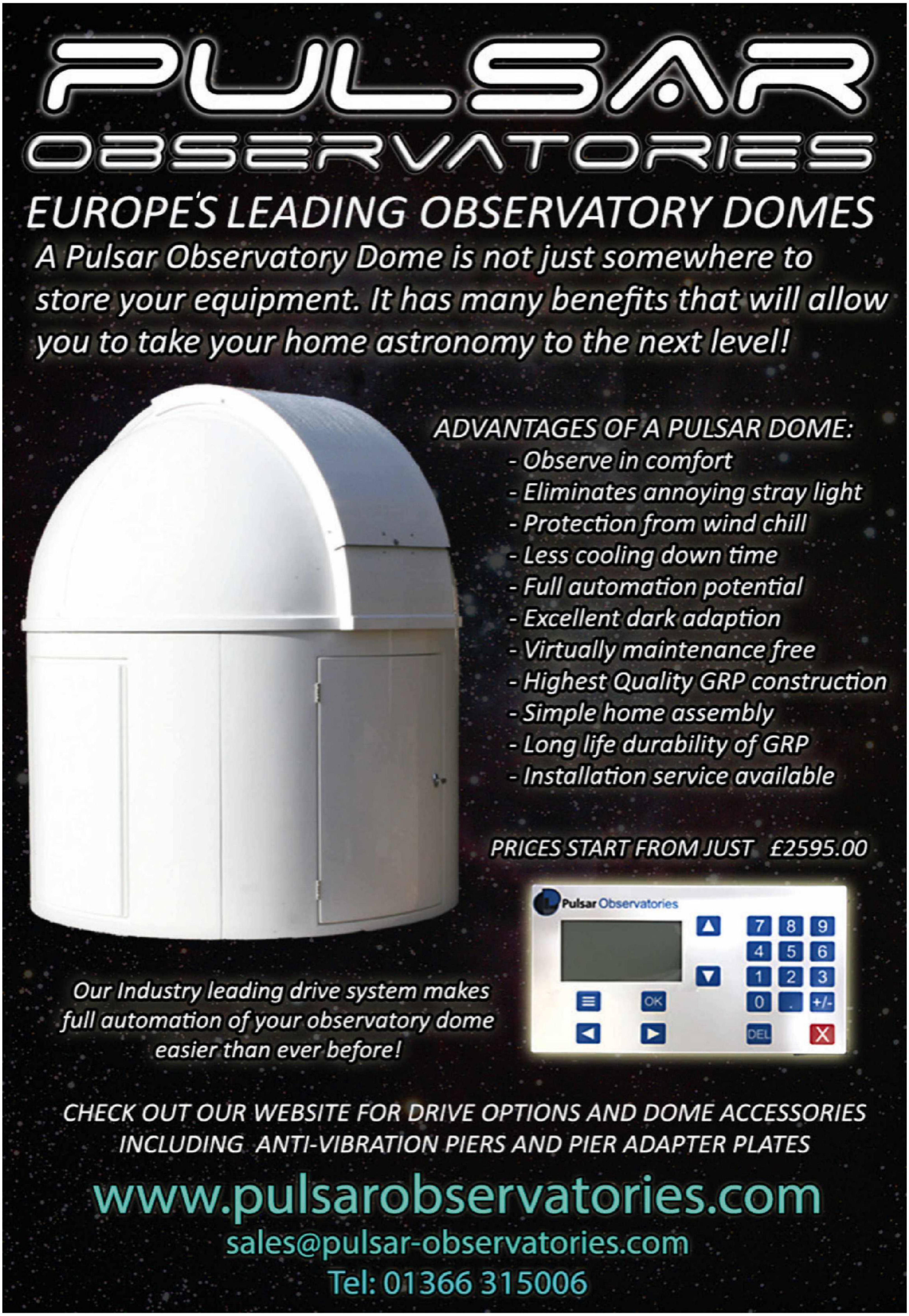
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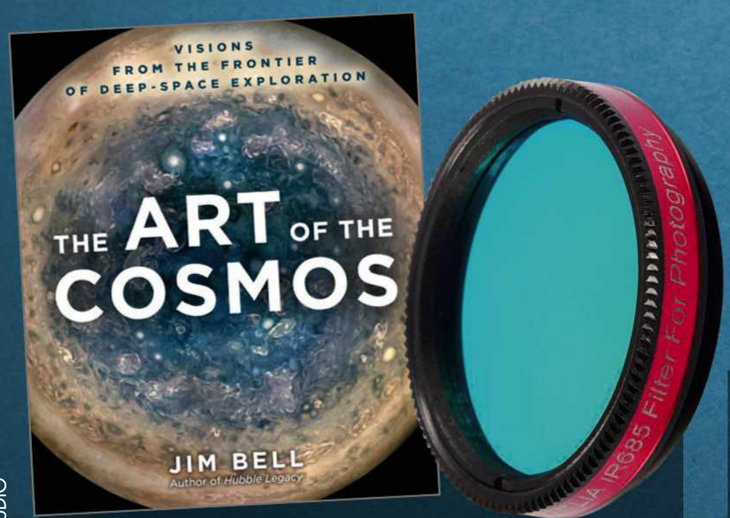
86
Does the midsized William Optics FLT 91 have the performance to match its £2k pricetag?



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PLUS: New books reviews, including Maggie Aderin-Pocock's latest, and a roundup of must-have astro gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

William Optics Fluorostar FLT 91 apo triplet refractor

Portable, superb build and performance? This could be the one you're looking for

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £1,949
- **Optics** FPL-53 glass apo triplet
- **Aperture** 91mm
- **Focal length** 540mm, f/5.9
- **Focuser** Dual-speed 3.3-inch rack and pinion focuser
- **Extras** Rotolock 2-inch adaptor, saddle bar, 40mm extension tube, Bahtinov mask, carry case
- **Weight** 5.6kg with tube rings, dovetail; 4.2kg without
- **Supplier** The Widescreen Centre
- **Tel** 01353 776199
- **www.** widescreen-centre.co.uk

Arriving in a single box, the William Optics Fluorostar FLT 91 was protected in a robust and well-padded soft carry case. We were immediately impressed with the quality of the case and how securely the telescope was supported inside. With twin handles that double as shoulder straps, allowing the case to be used as a rucksack, and additional space for accessories, it's a convenient prospect for astronomers and astrophotographers who like to travel.

As the name suggests, the FLT 91 is a 91mm (3.5 inch) aperture fluorite triplet telescope, with a focal length of 540mm. This provides a very useful f/5.9 focal ratio for both budding and more advanced deep-sky imagers. On inspection, this triple lens refractor appears very well built, with no hint of plastic and an excellent overall finish. The white OTA with red embellishments makes for a striking setup; it is also available with green or grey detail.

William Optics supplies numerous accessories as standard, including a 40mm extension tube, tube rings, Vixen saddle, carry handle and 2-inch Rotolock adaptor. We were also loaned the dedicated William Optics Flat 6AIII 0.8x focal reducer and field flattener, which can be purchased separately. Mounting the Fluorostar FLT 91 onto our Sky-Watcher EQ6-R, we found that obtaining balance was easy thanks to the long Vixen-style dovetail bar. In addition, we were able to mount our guide scope directly onto the carry handle that comes attached to the tube rings, which made setting up even easier.

Making connections

Popping a 32mm eyepiece in, the first thing we noted was that a 1.25-inch adaptor was not supplied. That's not an issue as we had our own, but it's something for visual users to be aware of. The Rotolock is an excellent addition that makes swapping accessories particularly easy. Slewing over to a setting Moon, we resolved some beautiful details and, later, a star test confirmed a flat field of view. This triplet definitely holds its own for visual astronomy.

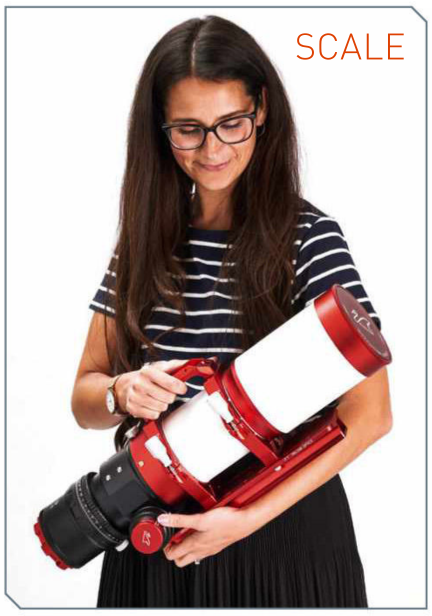
We were particularly keen to get imaging with the FLT 91 and so reached for the Flat 6AIII. The rack and ▸

Superior optics

A 540mm focal length and 91mm aperture make the FLT 91 suitable for both viewing and capturing deep-sky targets while still being portable, and its high-quality optics ensure excellent results. The FPL-53 glass (a type of synthetic fluorite) and triplet design minimises distortions such as chromatic aberration. This is because all colour channels are focused evenly, removing halo effects. The high-transmission (STM) coatings on all lenses also help to boost contrast, maximise light transmission and reduce unwanted reflections inside the optical system.

While these qualities ensure the FLT 91 provides an excellent field of view, the addition of the Flat 6AIII 0.8x reducer (not included) allows the focal ratio to reduce from f/5.9 to f/4.75 while providing a wider field of view. This grants faster imaging to the user and works well for capturing larger nebulae. All these features contribute towards clean data that makes processing easier, particularly for those new to astrophotography.

ALL PICTURES: @THESHED/PHOTOSTUDIO



Mounting accessories

The FLT 91 comes with a full suite of mounting options. The carry handle doubles as a mounting platform for guiding systems, while the Vixen-style dovetail is long enough to allow most setups to achieve balance. It is etched with a ruler that helps you easily identify the balance point.

Bahtinov mask

The built-in Bahtinov mask is a familiar feature of William Optics telescopes. It provides an excellent aid to focus and sharpen stars, which is particularly important for astrophotography. It is easy to access, simply by unscrewing the end of the lens cap. The clear mask also makes focusing easier.

Dual-speed focuser

The fine focuser helps increase precision, while the 3.3-inch rack and pinion barrel reduces vignetting for full-frame cameras and is engraved with a handy distance rule. The large focuser knob is easy to access in the dark. Meanwhile, the 360° field rotator means that you can reorientate your camera during an imaging session without losing focus.

2-inch Rotolock

Connecting accessories to the FLT 91 is easy with this adaptor. Rather than securing your imaging system on a single point, the Rotolock applies equal pressure around the entire barrel of your accessory. This further reduces the risk of slippage and makes changing accessories in the dark, or while wearing gloves, simple.

Dew shield

A robust, dew shield is an essential element for astrographs and visual telescopes. This full-metal version efficiently protects the FLT 91's optical elements from moisture, as it will quickly warm up with the application of a dew heater to the lens. It's retractable too, which boosts its portability.

IC 1318 in the Sadr region, taken with the FLT 91 in combination with a Starlight Xpress H694 camera, 8x 15' Ha, 4x 15' OIII

▲ The Tulip Nebula, captured using the same setup, 18x 5' Ha, 18x 5' OIII

▸ pinion focuser allows for 40mm of back focus, which we found with the flattener-reducer attached was sufficient. With our CCD camera on board, we swung over to the Sadr region in Cygnus and set our sights on IC 1318 (sometimes known as the Butterfly Nebula). We were pleased to see the Flat 6AIII did its job and provided pin-sharp stars from edge to edge. Opting for a bi-colour image, we captured about three hours of data to process. Next, we slewed to the Tulip Nebula and gathered a further couple of hours on this target.

Curious to see performance without a flattener attached, we removed the Flat 6AIII focal reducer. To achieve focus, we needed to use the additional 40mm extension tube supplied, plus an additional 40mm extension. However, we were pleased to note that we could only observe a slight curvature of the stars towards the edge of the field of view.

The 3.3-inch barrel of the focuser also enables the use of a full-frame DSLR. Attaching ours and firing off some flat calibration frames, we observed only minimal vignetting that could easily be removed in processing. For imagers, the FLT 91 is therefore suitable for a range of CCD and CMOS cameras.

Returning to our images, we found processing a breeze thanks to the clean data; no calibration frames were used for either target. With absolutely no vignetting and lovely round stars, we ended up with two very pleasing images to enjoy. As winter approaches, we imagine the FLT 91 would be an excellent deep-sky workhorse, and a reliable option that won't let its user down during those clear and long dark nights.

The William Optics Fluorostar FLT 91 granted us a stunning suite of astro images to enjoy and is small and light enough to remain portable for travelling astronomers. Its optics and performance will appeal to both imagers and visual users alike.

VERDICT

Build & design	★★★★☆
Ease of use	★★★★☆
Features	★★★★★
Imaging quality	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

KIT TO ADD

1. William Optics flattener 6AIII with M92 thread for FLT 91

2. William Optics 50mm red guiding scope with Rotolock

3. William Optics 48mm T-mount for Canon/Nikon cameras

@THESHED/PHOTOSTUDIO, PAUL MONEY X 2

Celestron StarSense Explorer 8-inch Dobsonian

Smartphone targeting and big aperture impress on this enjoyable 'Push-To' light bucket

WORDS: JAMIE CARTER

VITAL STATS

- **Price** £649
- **Optics:** 203mm (8-inch) Newtonian reflector
- **Focal length:** 1,200mm, f/5.9
- **Mount:** Altazimuth Dobsonian
- **App control:** StarSense Explorer
- **Extras:** Smartphone dock, 2-inch Crayford focuser, 25mm eyepiece, red dot finder, eyepiece rack, collimation cap, Starry Night Basic Edition
- **Weight:** 9.3kg tube, 10.3kg base
- **Supplier:** Celestron
- **Tel:** 0118 467 1200
- www.celestron.com

Celestron's StarSense technology has been around for a few years, but only on small telescopes aimed at beginners. It uses an app on your smartphone to find targets in the night sky, and this is the first time the StarSense smartphone holder has featured on an 8-inch aperture Newtonian reflector and Dobsonian mount. There is also a 10-inch model available.

StarSense on a Dobsonian is a revelation and is not to be confused with computerised 'Go-To' telescopes that automatically slew to objects at the touch of a button. StarSense is a manual 'Push-To' system that merely shows on a smartphone screen where to point the telescope, a bit like satnav does for drivers. The Celestron StarSense Explorer 8-inch Dobsonian isn't just easy to use, but is capable of giving first-timers an addictively impressive view of deep-sky and Solar System objects alike.

It is mounted on a manual altaz base that lacks any kind of motor, so the only astrophotography possible is afocal through the eyepiece, usually of the Moon. The base comes flat-packed and takes about 20 minutes to construct. The tube is best left in situ, merely turned vertically when in storage, but moving it outside is most easily done by separating tube from mount. That is fairly simple to do and both the mount and the tube have grab handles.

Stellar satnav

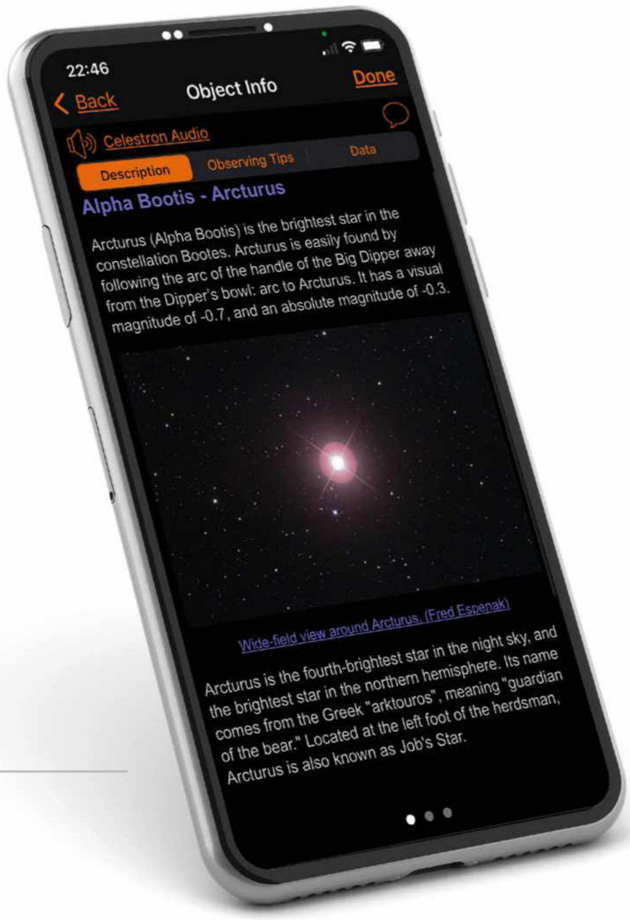
The base has a built-in eyepiece rack for the supplied 1.25-inch Celestron Omni Plössl eyepiece, whose 25mm focal length offers up to 48x magnification. Two slightly confusing inclusions are a red dot finder and free access to Celestron's Starry Night Basic Edition planetarium software for desktop computers. The former is handy for quick manual targeting, despite the presence of StarSense, but since it is placed on the opposite side of the telescope tube to the eyepiece it is very difficult to use. Meanwhile, the software is surely surpassed by the StarSense app and seems to be a hangover from previous products.

StarSense is highly impressive, but it is not perfect. As with all guided telescopes, this one needs to have its optics aligned with the night sky, but here what's important is the smartphone's view of a reflection of ▸

StarSense Explorer app

Celestron's StarSense Explorer app, available for Android and Apple smartphones, has been refreshed and expanded for the debut of this Dobsonian. Since this telescope's limiting magnitude is +14.2, it can glimpse targets much fainter than any of the small reflectors and refractors elsewhere in the StarSense Explorer range. Essentially a customised version of the SkySafari Plus app, StarSense Explorer has now been extended beyond the Messier objects, bright stars, the Moon and planets to include NGC, IC and many other catalogues of deep-sky objects.

You can find almost any target you want, though exploring beyond the curated 'tonight's best' list requires a manual search of its database. It's worth attaching wireless Bluetooth headphones to your smartphone, because the app includes audio commentary for hundreds of objects in its database. As well as being informative, it may encourage you to linger a little longer on objects.



Panning knob

The easiest way to complete aligning the telescope to an object using the StarSense Explorer app is by manually nudging this small knob. As well as being ergonomic, it can get an object back into the field of view without overreach, thanks to impressive azimuth and altitude bearings, the latter with variable tensioning.

Eyepiece and focuser

The telescope is supplied with a 2-inch Crayford focuser, a 2-inch to 1.25-inch adaptor and a 2-inch extension tube. This means any 1.25-inch or 2-inch eyepiece can be used, though only a 1.25-inch, 25mm Celestron Omni Plössl eyepiece is included.

Grab handle

At 9.3kg and 10.3kg, respectively, the telescope tube and base are tricky to lift together. Happily, they split into two pieces, which makes it reasonably easy to move them outside. They are best moved separately using their grab handles, though the Dobsonian base is bulky and awkward.

Accessory tray

A bolt-on accessory tray on the base can hold up to four eyepieces. However, while most telescopes have their accessory tray within easy reach, this one is housed low down at the front, which isn't particularly accessible.

KIT TO ADD

1. Portable battery for smartphone

2. 2m cable to attach a smartphone battery

3. Bluetooth earphones to hear in-app audio

▸ the stars above. As the smartphone sits in its holder, its camera is positioned over a mirror and reveals its view on screen. The trick is to match this with the position of a star in the telescope's eyepiece. The final act is to pinch-to-zoom on the smartphone screen to get that same star in its virtual crosshairs. Doing so requires a very bright star and a little confidence, though it's also possible to do all this in daylight with a distant chimney pot or a streetlight.

During use, StarSense frequently realigns itself, mostly after the telescope has been pushed correctly towards its target, at which point the software does more plate-solving to refine its position and guide you in with exacting precision. It is impressive, but a partly cloudy sky can give it problems. Happily, the app has a red light mode.

Considering its size, this telescope is surprisingly lightweight to use and easy to manipulate. Build quality is good and the Dobsonian base is stable; the bearings are just smooth enough. The tension can be tweaked on the altitude axis and it is possible to make very slight movements and, crucially, brake quickly. It is then easy enough to nudge the tube's panning knob to keep the target in the field of view.

Dobsonians are nicknamed 'light buckets' and this one lives up to that name. Cue sharp, bright, inverted views of the Andromeda Galaxy, M31, and the Great Globular in Hercules, M13, from a light-polluted location. Stars have four diffraction spikes, but they're lessened by XLT reflective coatings. Splitting double stars proved short work, with the constituent stars of the Epsilon Lyrae 'Double Double' star easily resolved. The rings of Saturn and cloud bands on Jupiter are also visible, though it does its best work on the deep sky. All in all, it is a hugely enjoyable telescope to use and will delight beginners and more experienced observers alike.

Smartphone holder

Bolted to the telescope's tube, this universal mount can accept any model of smartphone. A 35mm x 70mm mirror is positioned just above and behind where a smartphone's camera is. There are left-right and up-down controls to align the phone's camera with the mirror.

VERDICT

Assembly	★★★★☆
Build & design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

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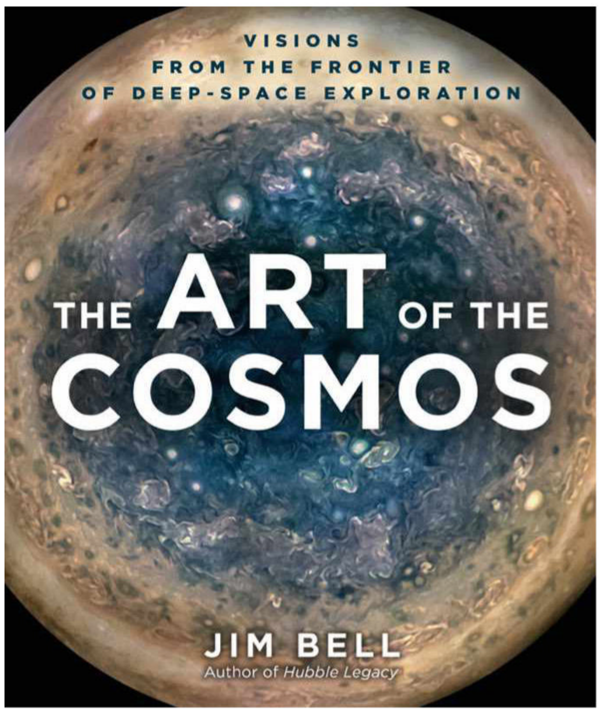
New astronomy and space titles reviewed

BOOKS



The Art of the Cosmos

Jim Bell
Union Square & Co
£30 ● HB

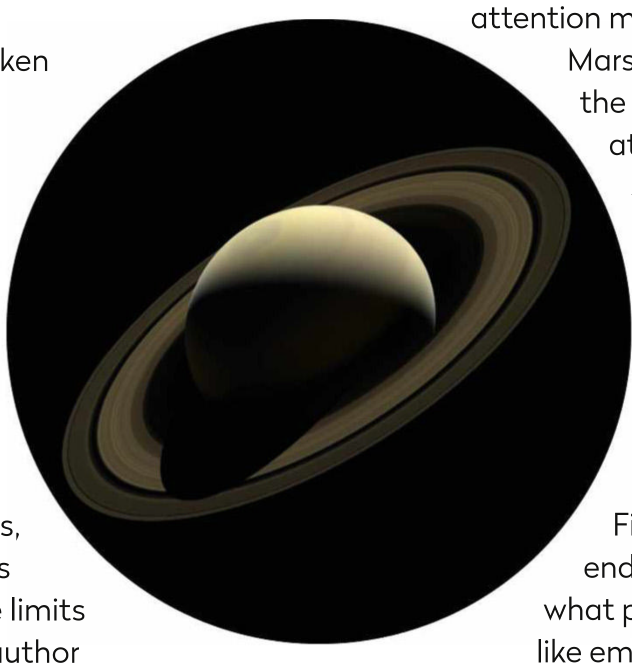
A book of pictures taken largely on a remote, automated basis by machines might ordinarily be a hard sell, but the images gathered here come from some of the most remarkable machinery ever built: mammoth telescopes, spacecraft and rovers exploring beyond the limits of human reach. As author Jim Bell, a former Jet Propulsion Laboratory engineer, argues in his accompanying text to this spellbinding collection, it takes *people* to plan, acquire and process these images.

Bell's own origin story in space photography is an example: helping oversee the Sojourner rover in 1997, he joined an attempt to capture a Martian sunset. Viking's images two decades earlier had shown twilit skies, but lacked the dynamic range to show the Sun itself. Sojourner's superior camera revealed an eerie blue solar disc, caused by Mars's dust soaking up reddish light. Now Martian sunsets have become a relatively commonplace sight, showing how technical progress governs what we get to see of the wider Universe.

The Art of the Cosmos starts with the Sun and journeys out across the planets of the Solar System and into the depths of space. The success of the book can be measured by the fact that the majority of its striking images are unfamiliar. Bell draws upon the work of an internet subculture of 'vicarious explorers', delving through space mission archives to uncover unfairly neglected images, such as the towering cliff on Comet 67P/Churyumov–Gerasimenko spied by ESA's Rosetta probe. Notably, Bell is also a landscape photographer, able to recount why factors like framing, contrast and depth of field mean that some photos draw our attention more than others.

Mars, understandably, is the photographic star attraction, with ringed Saturn coming a close second.

Beyond Pluto come psychedelic vistas of stars and galaxies, concluding with the famous Hubble Deep Field, picking out endless galaxies from what previously seemed like empty darkness. The James Webb Space Telescope is currently extending the limits of our observations, meaning this volume will require an update, but in the meantime it makes for a fine visual guide to our own and other galaxies. ★★★★☆



Saturn splendour: one of over 100 skilfully picked head-turners in the collection

NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

***Sean Blair** is senior editor for European Space Agency Technology and Navigation*

Interview with the author
Jim Bell

What's your favourite space image?

I don't have a single favourite, but I'm drawn to photos of the surfaces of worlds like the Moon and Mars, or the atmospheres of planets like Jupiter and Saturn. The range of colours and shapes are evocative of geologic or atmospheric scenes on Earth, yet these environments are extremely different from our own, so the comparison is illusory. I like the photographic tension between what seems familiar versus what's actually recorded: crushing gravity, extreme temperatures, deadly radiation.

Are you excited about JWST?

Who wouldn't be! The first images are stunning, especially compared to those taken by the Hubble Space Telescope. It's artistically compelling and scientifically attractive to see the Universe with a new set of eyes that's tuned into infrared. Webb's resolution, infrared sensitivity and instrument technology are going to rewrite astronomy textbooks, just like Hubble did.

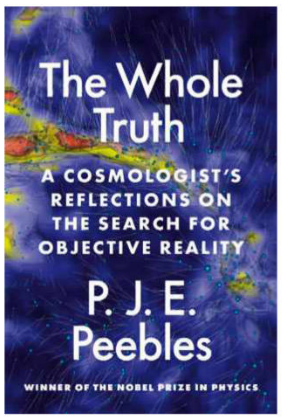
What worlds would you most like to see photographed?

Spectacular rocky mountain peaks on the Moon, huge canyons on Mars, towering columns of erupted lava on moon Io, billions of glistening chunks of ice in Saturn's rings, a sheer cliff of ice on moon Miranda, rugged glaciers on the surface of Pluto... the list goes on! These and many other wondrous places are destined to be part of a future 'Interplanetary Natural Park' system that our descendants will treasure and preserve.

***Jim Bell** is a professor at Arizona State University's School of Earth and Space Exploration*

The Whole Truth

PJE Peebles
Princeton University Press
£22 ● HB



It's not often that Nobel Prize winners share their views on the very nature of physical reality and the process of science. Princeton physicist James Peebles, one of the founders of the current standard model of cosmology, takes up the gauntlet in *The Whole Truth*.

Looking back at the history of cosmology over the past century, Peebles comments on our search for objective reality, convinced there is a single truth out there, but that our theories can only be approximations of that truth.

So why and how did we arrive at our current views of reality? According to Peebles, it's a mix of intuition, a search for elegance, bandwagon effect and chance. Many ideas, like Einstein's general theory of relativity, were originally accepted even without much empirical evidence. In most cases, he concludes, our theories are social constructs.

We hear many surprising examples of simultaneous or parallel progress in scientific discovery. Peebles describes a number of 'alternative histories' and concludes that our current cosmological views would have developed and matured anyway, independent of protagonists like Einstein, Gamow and himself.

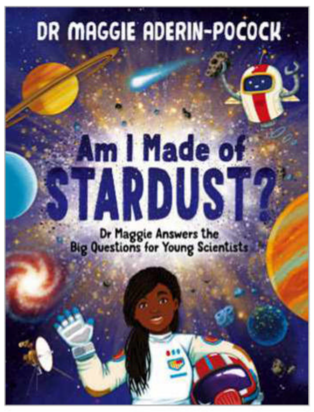
This is not an easy book. Not everyone may fully appreciate Peebles' elaborate musings on the philosophical and sociological aspects of our quest for knowledge. But if you're interested in a broad and thorough take on the nature of scientific discovery, this book is for you. ★★★☆☆

***Govert Schilling** is an astronomy writer and author of* Ripples In Time

Am I Made of Stardust?

FACTS FOR KIDS

Maggie Aderin-Pocock
Michael O'Mara
£12.99 ● PB



As anyone who has attempted to talk to a child about space will know, young minds come up with endless, incredible, bizarre questions, though it's often hard to respond with a satisfying, accessible answer. In *Am I Made of Stardust?* Maggie Aderin-Pocock has managed to do exactly that.

This is a fantastic questions-and-answers book, with vibrant illustrations. The first chapter covers the big questions about space, from the Big Bang and how big the Universe is, to what aliens might look like. The second focuses on our own Solar System – how we land a rover on Mars and whether Pluto is a planet (controversial!). The last chapter focuses on human space exploration, including what space smells like and how you too can become an astronaut.

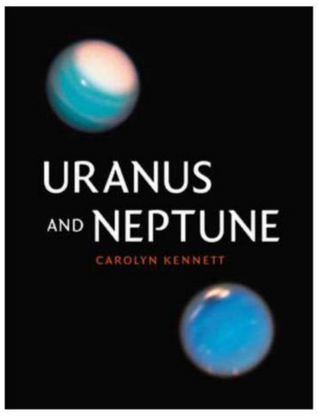
Aderin-Pocock gives thoughtful, clever answers to all these questions and more. These answers are short but engaging, accessible but without the half-truths we often end up telling young children about science. There are also a few at-home experiments to try out – great for curing rainy day boredom. The advertised 9–11 years is probably a little on the older side of the ideal audience: this would be a great book to read with younger children.

This is a book any kid who's fascinated by space (which is, frankly, most of them) will enjoy, but also a valuable tool for any adult frequently left stumped by the strange and varied questions of primary-school-aged children. Hopefully this will, briefly at least, satiate their curiosity. ★★★★★

***Katie Sawers** is a science writer specialising in the history of astronomy*

Uranus and Neptune

Carolyn Kennett
Reaktion Books
£25 ● HB



Unlike the other planets in our Solar System, the 'ice giants' Uranus and Neptune were discovered in the modern era and so are solely scientific objects with no ancient cultural connotations. This latest book by Carolyn Kennett in Reaktion Books' Kosmos series is a concise summary of our knowledge of both planets, as well as their numerous moons.

Neptune is the only planet whose discovery was predicted – a result of perturbations in Uranus's orbit – and the book carefully unpicks the complex tale of this discovery, showing who should be credited with which aspect.

We learn of the two planets' similarities: their rocky cores, their outer atmospheres containing methane, their magnetic fields unaligned with their axes of rotation. But we also learn about their differences: Uranus's odd axis of rotation nearly at right angles to its orbit, for example, is unique in the Solar System, likely the result of a collision in the past; Neptune emits far more heat than it absorbs from the Sun.

Getting to grips with the history of these planets is important not just for our understanding of our own Solar System, but also for learning about planetary formation in the Universe more generally. After all, around one-third of all the exoplanets discovered so far are classed as Neptune-like.

Much of what we know about Neptune and Uranus is based on Voyager 2's fly-bys in the late 1980s and its unforgettable images. This book is, rightly, as much an account of the technical triumphs of Voyager 2 as it is the story of the planets themselves, and it makes the case for a future, dedicated mission to these mysterious blue worlds. ★★★★☆

***Pippa Goldschmidt** is a science, history and astronomy writer*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Explore Scientific ReflexSight LED finder

Price £65 • **Supplier** Telescope House • **www.telescopehouse.com**

This novel viewfinder gives an unmagnified view of the entire sky, not just a zoomed-in portion of it. Using the red target circles, use this view to line up your scope or large binoculars with your target area.

2 Antlia 1.25-inch IR pass planetary filter

Price £40 • **Supplier** First Light Optics • **www.firstlightoptics.com**

Centred on a wavelength of 685nm, this filter mainly lets in infrared light. Infrared is affected much less by air turbulence, so it's a great option for imaging planets. Can be combined with frames at other wavelengths to increase crispness and clarity.

3 Jansport Cross Town backpack

Price £33 • **Supplier** The Back Packer • **www.thebackpacker.co.uk**

Whether for work or school, this backpack is a stylish choice, decorated with a sea of stars and nebulous blues and purples. Has a front zip pocket and a side pocket for your water bottle.

4 Askar Vixen-style dovetail plate

Price £41 • **Supplier** Widescreen Centre • **www.widescreen-centre.co.uk**

Combining function and form, these 300mm bars have a number of holes allowing you to mount your equipment exactly as you want, and come in a choice of colours to give your setup a touch of personality.

5 Giotto 185 smart flat field generator

Price £325 • **Supplier** 365 Astronomy • **www.365astronomy.com**

ADVANCED Flat frames vastly improve your final image quality, and with this device you can take them in seconds. Locking onto the front of your scope, it uses LEDs to produce a uniform light at a similar temperature to the Sun. This fits 185mm apertures, but other sizes are available.

6 Merino neck gaiter

Price £29.99 • **Supplier** Mountain Warehouse • **www.mountainwarehouse.com**

Keep warm during a long observing session by stopping cold winds from sneaking past your collar with this neck gaiter. Made from lightweight and breathable merino wool blended with polyester.

Melissa Brobby interviews Ben McKinley

Q&A WITH A RADIO ASTRONOMER

The Moon isn't just Earth's natural satellite. By blocking background galactic radio signals, it could be the key that unlocks the secrets of the early Universe

How can radio astronomy tell us about the early Universe?
When the early Universe expanded and cooled sufficiently, protons and electrons formed neutral hydrogen. The first stars and galaxies then 'reionised' the hydrogen – that is, their photons interacted with the atoms, causing the electrons to separate. This is the Epoch of Reionisation (EoR). Neutral hydrogen emits photons at a wavelength of 21cm. But since the EoR, the wavelength of these will have been redshifted (stretched by the expansion of the Universe) to between one and three metres, in the radio part of the electromagnetic spectrum. How this redshifted 21cm signal looks tells us about these first stars and galaxies that reionised the hydrogen.

What are the main challenges of detecting this signal from the Epoch of Reionisation?
This goal is fraught with difficulty, as the signal is weak and obscured by much brighter radio emissions in the foreground, coming from objects such as radio galaxies and electrons travelling at near light speed in our Milky Way. This is where the Moon comes in; it occults the sky, providing variation to the otherwise featureless average radio signal we are looking for. If we know the angular size of the Moon and its brightness as a function of frequency or wavelength, then we can use observations from the Murchison Widefield Array (MWA) – a low-frequency radio telescope in Western Australia – to deduce the average background signal at different frequencies.

Why do you use the Moon for this rather than another celestial body?
The Moon acts as a known reference against which we can measure the average background of the sky. The global average is otherwise invisible to the MWA, which is sensitive only to angular variations of the signal. In theory, any occulting shape could be used; the Moon just happens to be an ideal size in the sky and we think we know its brightness as a function of frequency.

▲ **The 4,096 antennae of the Murchison Widefield Array (MWA) in Western Australia were trained on the Moon for the comparative study**

Ben McKinley is a research fellow at Australia's Curtin University, specialising in understanding the complex structure and behaviour of radio galaxies

NATASHA HURLEY-WALKER/MWA COLLABORATION & CURTIN UNIVERSITY

How did you use the Murchison Widefield Array for your research?
The MWA could observe the Moon between 72MHz to 230MHz. The telescope pointed at the Moon one night and on a subsequent night at the same local sidereal time, the same area was observed. In the second observation the Moon would not be in the field of view as it would have moved away, due to its orbit around Earth. This allowed us to subtract one set of images from the other, effectively removing the rest of the sky and leaving an imprint of the Moon. The different images were then analysed to extract the global background sky that the Moon was occulting.

What problems did you run into using this method?
The main problem was that we couldn't assume the Moon was a black body [an object that absorbs radiation perfectly] of a constant temperature, because the Moon reflects radio signals originating from Earth back down to the telescope. So what happens is you get a bright point in your images at the Moon's centre, as it acts like a mirror. This is especially a problem between the frequencies of 87MHz and 110MHz. However, it turns out that reflections of sunlight and the heating of the surface by the Sun is a much smaller effect, and so for our purposes the phase of the Moon doesn't matter.

How many observations have you made?
We've made observations over several nights to a total of around 250 hours and we are still in the process of analysing and publishing the data. So far we only have one night each of an on–off Moon pair. As we can't cover the whole frequency range in one go we needed to split up the observations, such that we ended up with about 70 minutes 'on-Moon' time per frequency channel. This was enough to demonstrate that our process worked and could measure the global foreground sky signal from the Milky Way – it was about 10,000 times brighter than the expected global 21cm signal.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NEW!
Introducing the Explore Scientifc Two-Room Pop-UP Observatory Tent / Weather protection for telescopes- £254
Explore Scientific iEXOS-100 Wifi Mount £395
PMC EIGHT
PRECISION MOTION CONTROLLER
Check out the Explore Scientific Deep Sky Cameras - featuring 1.7, 7.1 & 16 MP Sensors. In addition to these, check out the new actively cooled 8.3MP 4K Camera - only £533!
NEW!
16MP - £942
1.7MP - £1405
7.1MP - £2250
Explore Scientifc 127mm Apos FROM £1599
Explore Scientifc 50mm & 60mm guidescopes - FROM £169
NEW!
Introducing the new Explore Scientifc 70, 82, 100 and 120mm Astrobinoculars + U-Mount. Exceptional quality & value for money. Starting from £1036
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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch a total eclipse of the Moon and take a walk in the Magellanic Clouds

When to use this chart

1 Nov at 00:00 AEDT (13:00 UT)
15 Nov at 23:00 AEDT (12:00 UT)
30 Nov at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

NOVEMBER HIGHLIGHTS

On 8 November a total eclipse of the Moon is visible from Australia. From the east coast the penumbral phase begins by moonrise, with the main shadow (umbra) underway by the end of twilight. It begins at 20:16 and ends at 21:42 AEST, with maximum eclipse at 20:59 AEST. From central Australia the early part of totality has some twilight interference. Sadly for Western Australia, the Moon already reaches mid-eclipse as it rises. At the same time the Sun has just set.

STARS AND CONSTELLATIONS

High in the southern sky is a view unique to the Southern Hemisphere, the Magellanic Clouds. Like our Galaxy, their 'milky' appearance is from the combined light of millions of stars. The smaller, SMC (mostly in Tucana) precedes its larger companion, the LMC (in Dorado) across the sky. The SMC appears to have no structure, while the LMC has a distinct east–west equatorial bar. Under dark skies the 'clouds' are good naked-eye objects; through binoculars they are brilliant.

THE PLANETS

Saturn is getting lower in the northwest evening sky, setting around midnight at month's end. Jupiter and Neptune are easily seen due north around the end of twilight. As Mars heads towards opposition next month it can be seen rising in the mid-evening sky, its brightness exceeding the luminaries of Orion and rivalling Sirius. Uranus is at opposition and visible all night. Venus and Mercury remain too close to the Sun; both return to the evening in December.

DEEP-SKY OBJECTS

This month we will use the Magellanic Clouds to find two other gems in the far southern sky. Located 1° west of the SMC is the spectacular globular cluster 47 Tucanae (RA 0h 24.1m, Dec –72° 05'). A brilliant object in any telescope, you will need at least 150mm instruments to see individual stars. At mag. +4.0, it's visible to the unaided eye and binoculars even give a glimpse of its bright, compact core.

Turning to the LMC, binoculars will reveal a bright nebulous spot just above (north of) the eastern end of the central bar – a magnificent super star cluster, the Tarantula Nebula (RA 5h 38.7m, Dec –69° 06'). Only a 150cm telescope is needed to reveal this complex of nebulae and star clusters that extends for approximately 1°. The legs of the spider are the loops of nebulae clearly seen extending from its centre.

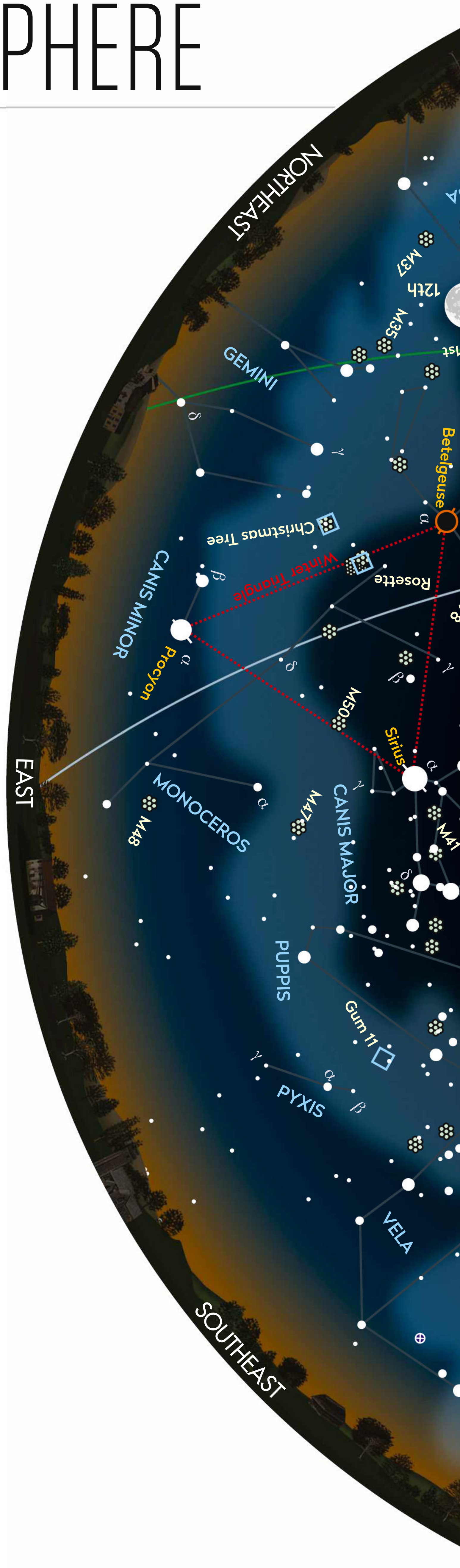
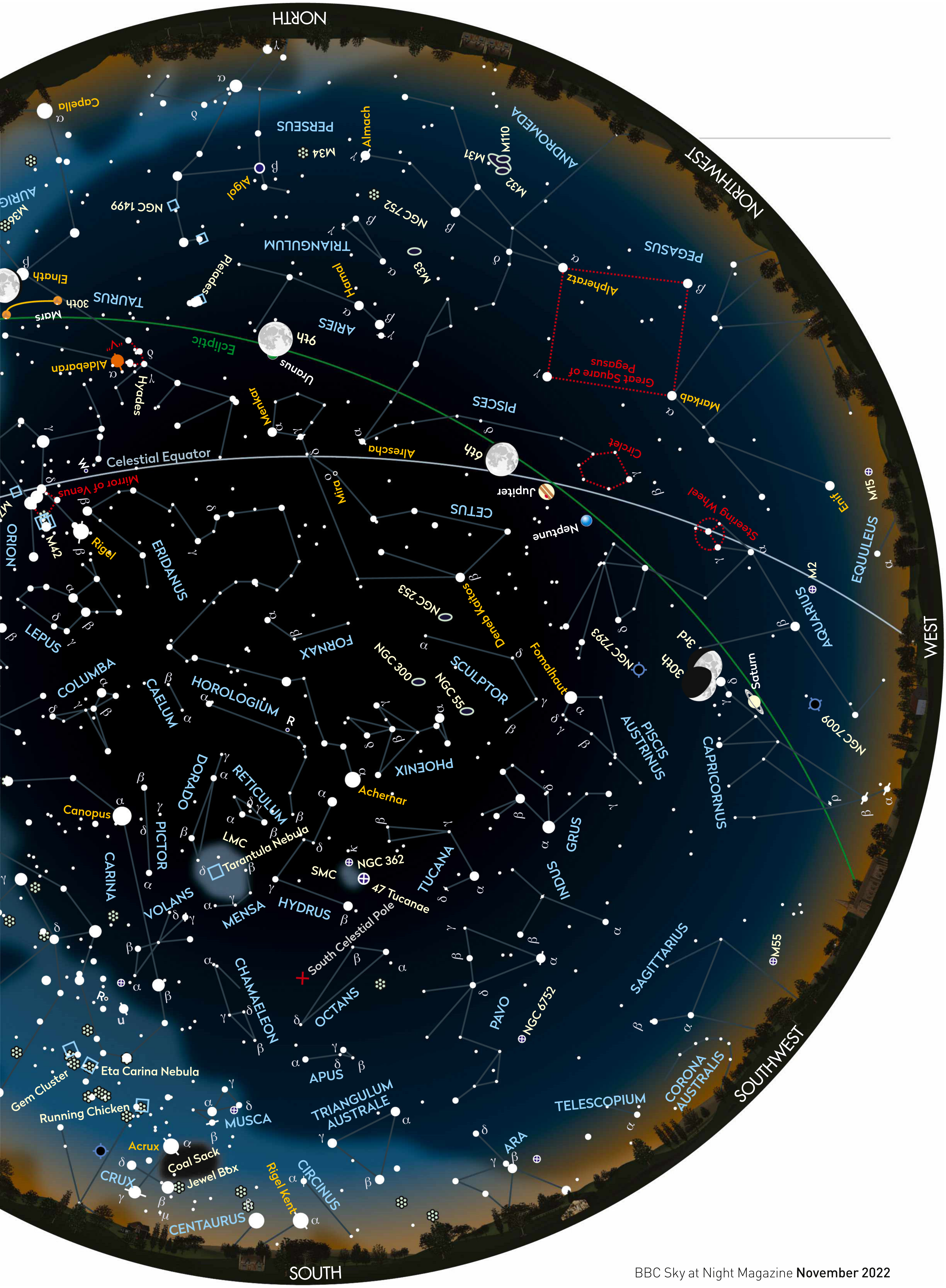


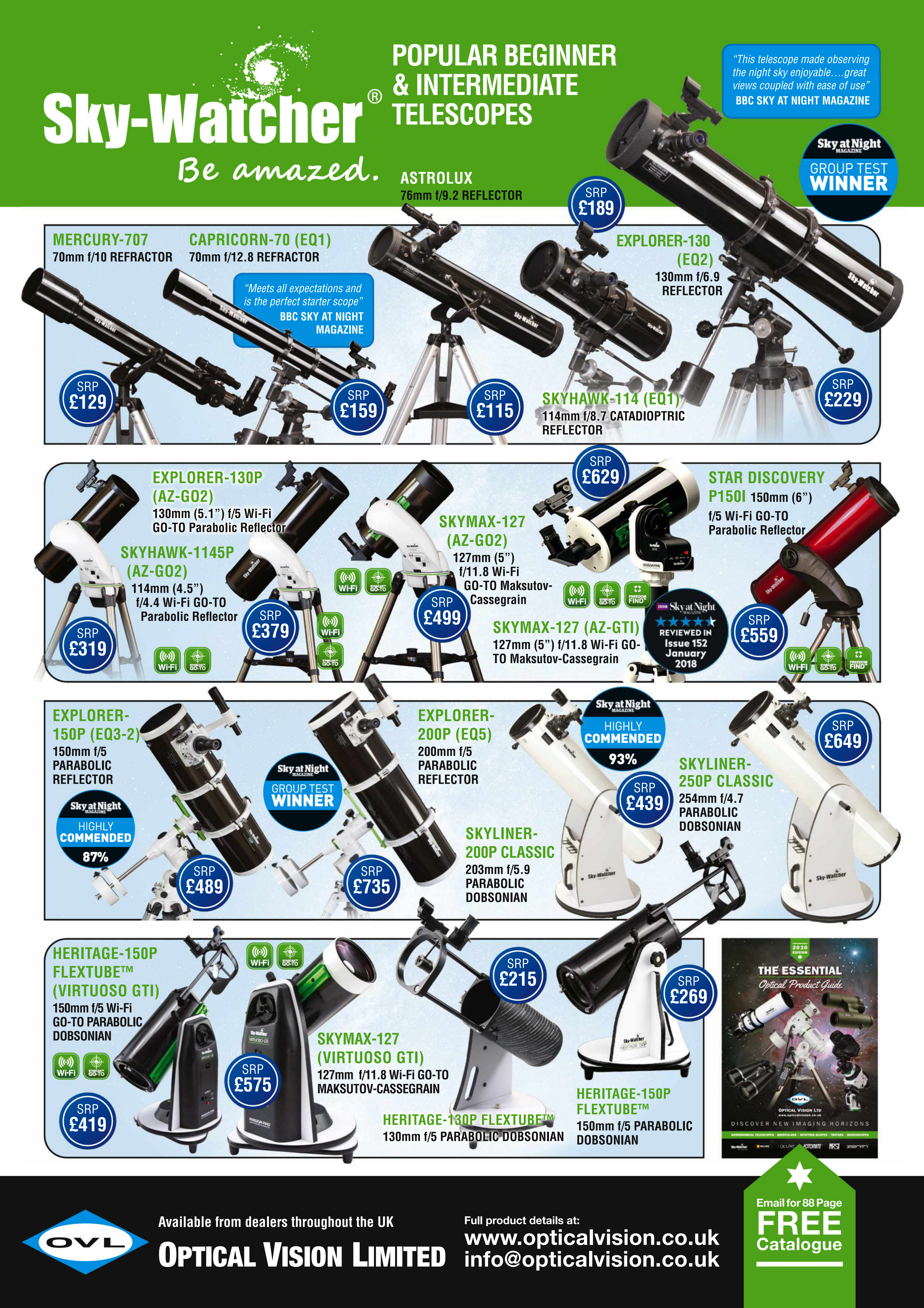
CHART: PETE LAWRENCE

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER



NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
PERSEUS
M34
Almach
ANDROMEDA
M31
M110
M32
Algol
NGC 1499
NGC 752
TRIANGULUM
M33
Hamal
PEGASUS
Alpheratz
Pleiades
Elnath
TAURUS
30th
Mars
ARIES
9th
Ecliptic
Uranus
Great Square of Pegasus
Markab
"V"
Aldebaran
Hyades
Menkar
PISCES
Circlet
Alrescha
6th
Celestial Equator
Mirror of Venus
Mira
Jupiter
CETUS
Steering Wheel
Enif
M15
Neptune
EQUULEUS
ORION
M42
Rigel
ERIDANUS
M2
AQUARIUS
NGC 253
Deneb Kaitos
LEPUS
FORNAX
3rd
30th
NGC 7293
Fomalhaut
Saturn
COLUMBA
CAELUM
HOROLOGIUM
NGC 300
SCULPTOR
NGC 55
NGC 7009
PISCIS AUSTRINUS
CAPRICORNUS
DORADO
RETICULUM
PHOENIX
Achernar
Canopus
PICTOR
LMC
Tarantula Nebula
NGC 362
SMC
47 Tucanae
TUCANA
GRUS
CARINA
VOLANS
MENSA
HYDRUS
South Celestial Pole
INDUS
SAGITTARIUS
M55
CHAMAELEON
OCTANS
PAVO
NGC 6752
Eta Carina Nebula
Gem Cluster
APUS
TRIANGULUM AUSTRALE
TELESCOPIUM
CORONA AUSTRALIS
Running Chicken
MUSCA
Acrux
Coal Sack
Jewel Box
CRUX
Rigel Kent
CIRCINUS
ARA
CENTAURUS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